COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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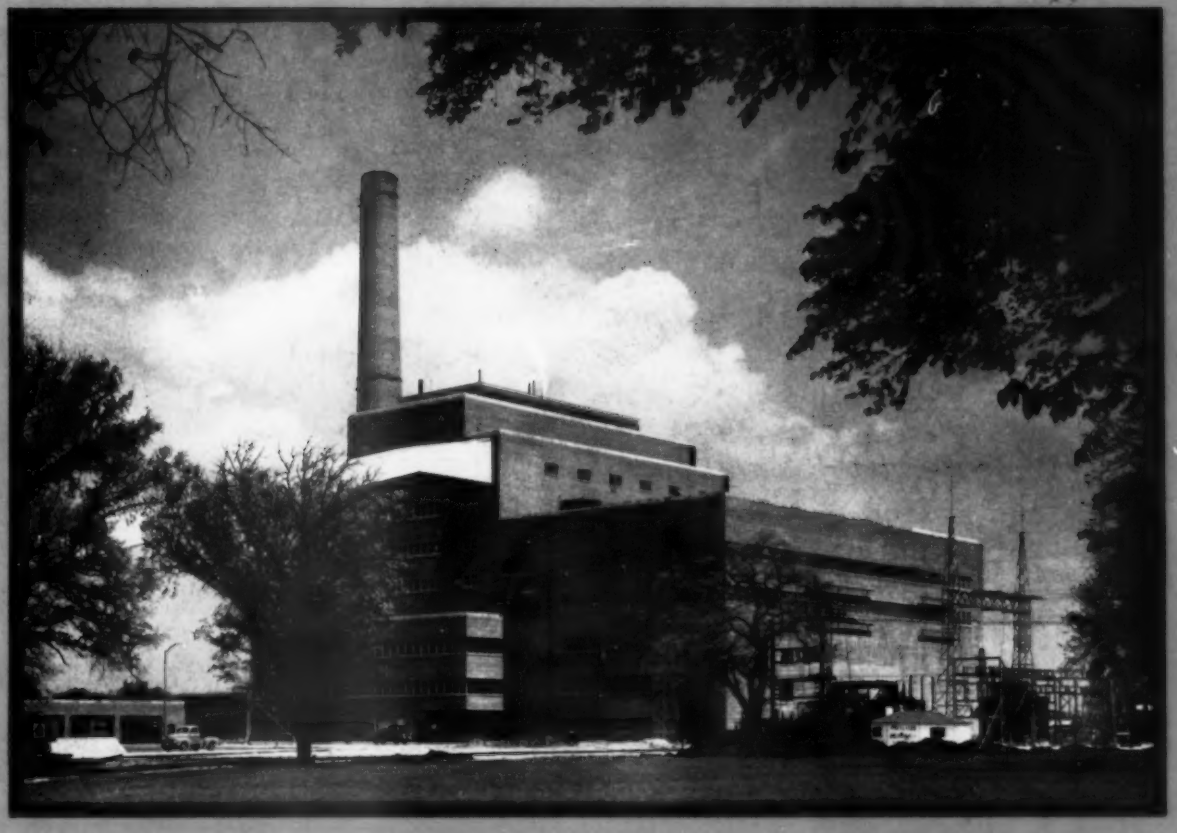


Hennepin Station of Illinois Power Company; see page 47

The Gas Turbine as a Combustion Topping Unit

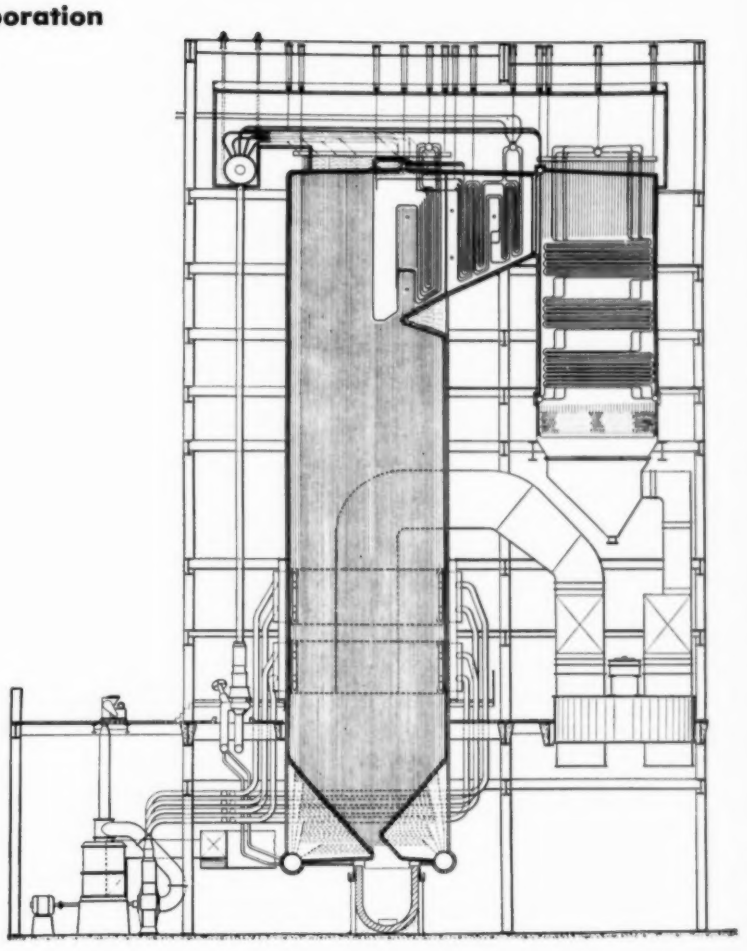
Cleaning Regenerative Air Preheaters—II

Acid Regeneration of Cation Exchangers

STATE LINE STATION

Chicago District Electric Generating Corporation
Commonwealth Edison System

C-E controlled circulation boilers



The C-E Unit shown above is now in process of engineering for the State Line Station of the Chicago District Electric Generating Corporation, Hammond, Indiana. State Line Station is one of the eleven generating stations of the Commonwealth Edison System. Sargent and Lundy are the consulting engineers.

This unit is designed to serve a 191,000 kw turbine-generator operating at a throttle pressure of 2000 psi with a primary steam temperature of 1050 F, reheated to 1050 F.

The unit is of the controlled-circulation, radiant type. It is a separated furnace arrangement with secondary superheater surface at the outlet of one furnace and reheater surface at the outlet of the other. Primary superheater sections and economizer surface follow both the secondary superheater and reheater surfaces. Regenerative air heaters follow the economizer surfaces.

Pulverized coal firing is employed using bowl mills and tilting, tangential burners.

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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 25 **No. 3**

September 1953

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GERALD S. CARRICK
Business Manager

ALFRED D. BLAKE
Editor

GLENN R. FRYLING
Assistant Editor

CARL G. UDELL
Circulation Manager

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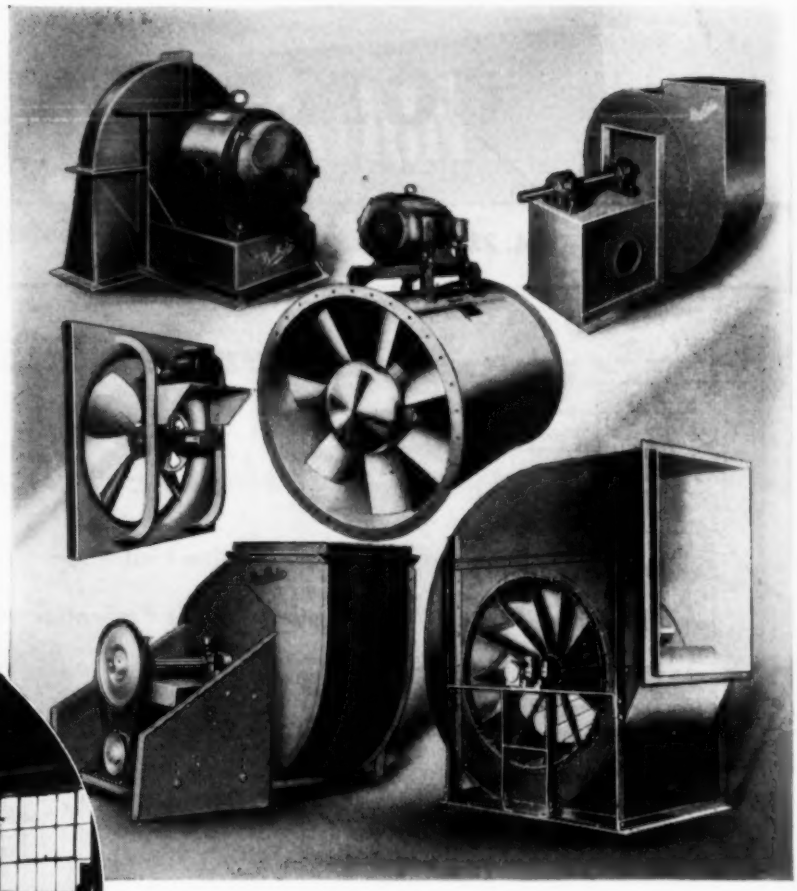

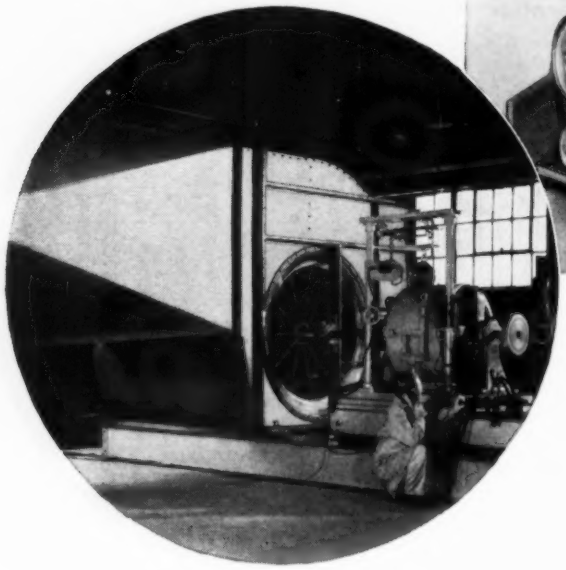

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Editorials

Cleaner Air Week

As a part of its continuous crusade against atmospheric contamination by smoke, fly ash, industrial fumes and odors, the Air Pollution Control Association, from its executive offices in Pittsburgh, has called for nation-wide observance of "Cleaner Air Week," October 18 to 24.

Federal, state and municipal authorities, as well as industrial executives, chambers of commerce and various civic organizations, are being urged to cooperate, and the daily press, radio and television are expected to play important rôles. Also, in order to catch the attention of the general public, posters will be widely displayed. The idea is, through education and an intelligent approach to the problem, to promote the prevention of air pollution which will be shown as an economic loss as well as annoying and in many cases harmful.

According to a recent survey made by the ASME Committee on Air Pollution Control, there are close to a hundred laboratories currently engaged in studies of various phases of the problem. Moreover, judging from the number of engineering and medical papers presented, local publicity accorded the subject, and the numerous ordinances enacted during the past few years, it would seem that the public has become notably conscious of the problem. Hence an annual intensive campaign such as "Cleaner Air Week" is important in keeping interest from lagging.

Combined Steam-Gas Turbine Cycles

Many proposals have been made to combine steam and gas-turbine cycles. The strongest appeal of most of these schemes is on the grounds of substantially increased thermodynamic efficiency. But other arguments have been advanced which indicate that combined cycles also offer advantages in terms of flexibility of operation.

Consider the case of a small steam plant which generates both power and process steam. Should there be a marked increase in power demands without a corresponding rise in steam consumption, a combined cycle offers the possibility of making up the power deficiency. In this instance one method would be to pass the boiler flue gases through the gas turbine. On the other hand, if there is a substantial increase in steam demand without a corresponding rise in power, it might be advantageous to use a gas turbine in combination with a waste heat boiler. Still another possibility is that of employing the gas turbine as a topping unit. Prof. J. F. Lee, in an article appearing in this issue, writes about the feasibility of utilizing the exhaust gas from a gas turbine to support combustion in an existing steam generator.

To date most of the proposals for combined steam-gas turbine cycles have been in the nature of theoretical studies. It is to be hoped that more effort will be put forth to build new plants or modify existing ones to determine the economic practicality of the combined cycles.

Looking Forward

The National Association of Manufacturers has recently made a study of the anticipated growth in our national labor force, the term "labor" being employed broadly, and the additional capital investment that will be needed for industrial expansion to provide the requisite employment. The survey indicates that in the decade from 1950 to 1960 the number of workers, of all categories, will have increased by 7,800,000, whose employment will require an additional capital investment of 94 billion dollars. By 1975 it is estimated this figure will have increased to 294 billion. These figures are based on the present national average of $12,000 of investment per worker.

One may recall that the Bureau of Census announced a total population in the United States of 160 million on August 10, 1953, stating further that the current net gain of births over deaths, immigrants and emigrants, amounted to five per minute or approximately 7,600,000 per year. In confirmation one only has to look at the greatly overcrowded schools now accommodating some 27 million children with a realization that by 1975 most of these children will have grown up and been in the market for productive jobs.

This explains, in part, the steady *normal* expansion in power facilities to meet increasing industrial and domestic demands, as well as the necessity for long-range planning in power supply.

The N.A.M. points to the lamentable fact that high taxes are absorbing much of the money that might otherwise be devoted to industrial expansion and to meeting other pressing needs. It cites this as an argument for greater economy in government. One can wish further that world conditions were not such as to make necessary such huge expenditures for defense.

The Gas Turbine as a Combustion Topping Unit

By J. F. LEE*

Following is an analytical study undertaken to determine the feasibility of utilizing exhaust gas from a gas turbine to support combustion in an existing steam generator, the effect of such an arrangement on steam generator performance and the combined heat rate. Indications are that, under certain conditions, the arrangement improves the performance of the steam generator and secures for the combined plant, over a wide range of load, a heat rate which is superior to that of the steam power plant or the gas-turbine power plant in independent operations.

THE simple open-cycle gas turbine operating on the Brayton cycle offers many well-known advantages among which are simplicity of operation and construction, light weight, compactness, low initial cost and low installation changes. Further advantages are found in the ease and speed with which this type of plant can be installed. Unfortunately, the metallurgical limitations imposed on turbine inlet temperature and the high temperature of heat rejection in the gas-turbine exhaust gases result in a poor heat rate. Furthermore, the unfavorable off-design performance characteristics of the compressor combined with governing by reduction of turbine inlet temperature cause a marked increase in plant heat rate at other than design load. Of course, the heat rate of the basic plant can be improved to a considerable extent by adding regeneration, intercooling and reheat but these refinements deprive the plant of much of its simplicity and increase the initial investment materially.

The proposal here is to employ a gas turbine as a combustion topping unit in an existing steam power plant where there is a need for an immediate increase in installed capacity. The term combustion topping unit, is intended to mean that the gas-turbine exhaust gases replace in whole or in part the normal combustion air requirements of the steam generator. In this scheme the gas turbine exhausts directly to the steam generator at windbox pressure, thereby utilizing existing heat transfer equipment to recover a portion of the energy in the gas-turbine exhaust gases in the form of equivalent fuel.

The disadvantage of poor part-load heat rate in the gas-turbine power plant can be eliminated by taking load fluctuations on the steam power plant. To accomplish this the size of the gas-turbine power plant must be such that all the gas-turbine exhaust gases can be used over a wide range of loads on the steam power plant. Preheated air may be employed to supplement the gas-turbine exhaust gases in order to provide the required quantities of combustion gas as the need arises.

The principal objectives sought in employing a combustion topping unit are:

(*a*) to increase the capacity of an existing steam power plant quickly and cheaply,

(*b*) to recover in an existing steam generator an effective portion of the energy in the gas-turbine exhaust gases,

(*c*) to improve combustion and heat transfer conditions in the steam generator by providing combustion gas at a temperature higher than that of available combustion air,

(*d*) to secure a heat rate for the combined plant which is superior to that of either the gas-turbine plant or steam power plant in independent operation as a result of *b* and *c*,

(*e*) and to make possible the utilization of lower grade fuels.

How nearly these objectives can be realized depends in large measure on the physical attributes of the steam generator. Therefore it is difficult, if not impossible, to develop quantitative relationships of general application.

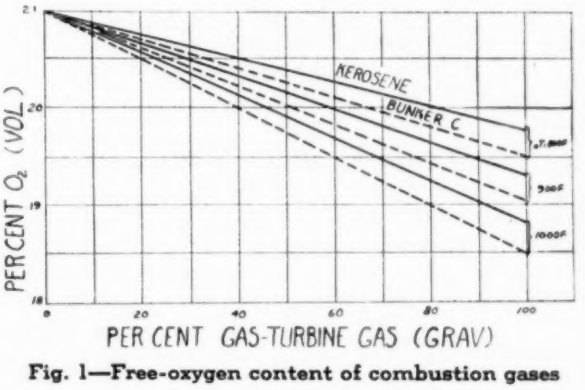


Fig. 1—Free-oxygen content of combustion gases

However, some qualitative observations which are of direct value in engineering a particular installation can be examined.

Free-Oxygen Content of Combustion Gases

One of the prime factors of importance is the free-oxygen content of the combustion gases. Accurate information is lacking, from tests, as to the chemical composition of gas-turbine exhaust gases. However, a reasonably accurate determination can be made by combustion calculations.

* Associate Professor of Mechanical Engineering, North Carolina State College, Raleigh, N. C.

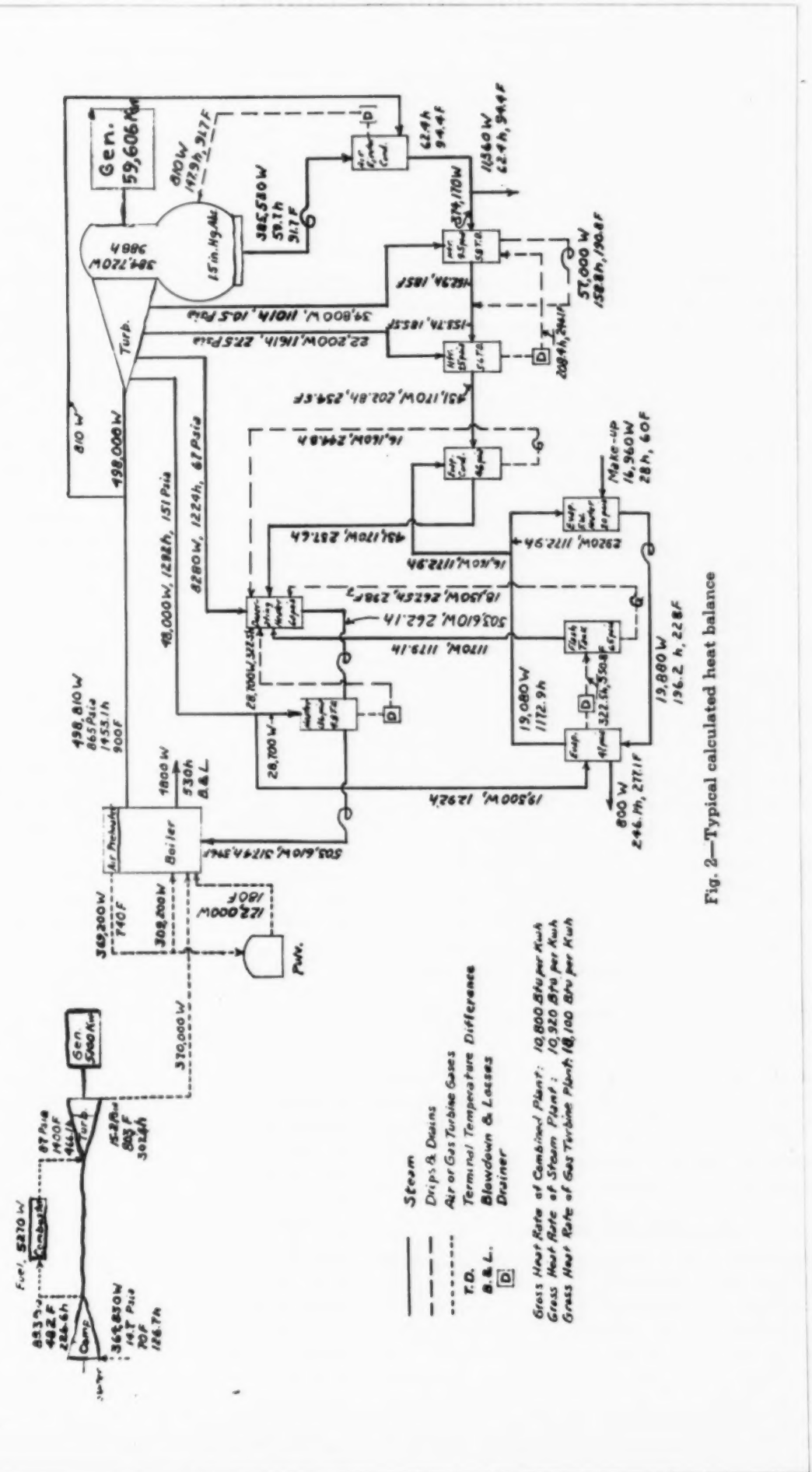


Fig. 2—Typical calculated heat balance

One fact which must be appreciated is that large quantities of air are required to cool the products of combustion to an acceptable temperature before entering the turbine. Hence the ratio of total air to fuel may be of the order of 6.5 times the stoichiometric air-fuel ratio. The actual value of this ratio depends on the permissible temperature rise across the combustor and the carbon-hydrogen ratio of the fuel. Because the products of combustion in the combustor are so heavily diluted with air the free-oxygen content of the resulting gas-turbine gas is not appreciably lower than that of air.

Under many circumstances it is necessary to supplement the gas-turbine exhaust gases with air for reasons to be discussed later. The resulting mixture which comprises the combustion gas is oxygen enriched to a

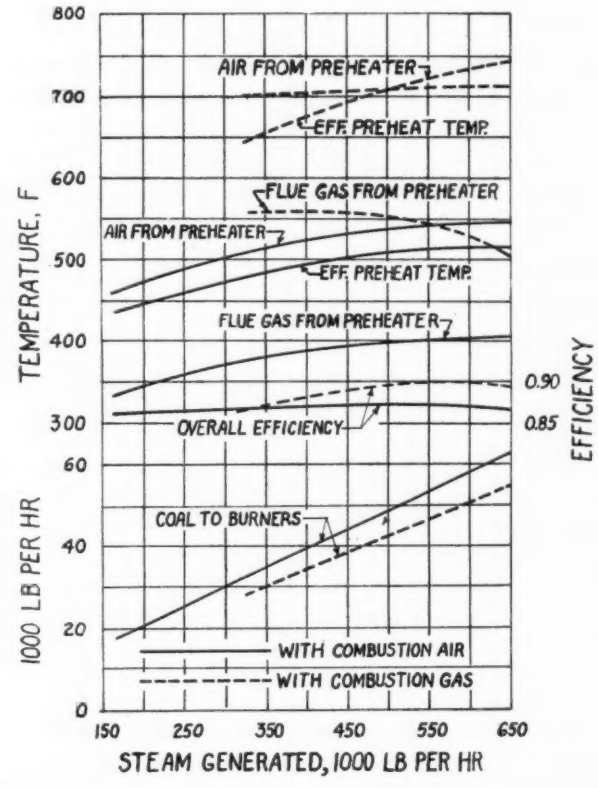


Fig. 3—Performance characteristics of steam generator

degree depending on the air concentration in the mixture. Fig. 1 shows the free-oxygen content of combustion gas as a function of the concentration of gas-turbine exhaust gases in the mixture for three temperature rises across the combustor. Separate curves are given for burning kerosene and Bunker C fuel oil.

Combustion Topping Unit

As stated before, the combustion unit is nothing more than a simple open-cycle gas-turbine plant. In order to take advantage of increased net output from the plant at lower ambient air temperatures and to maintain a constant exhaust temperature from the turbine it is necessary to keep the turbine inlet temperature constant at its design value. When peak demands are met in winter this scheme has the triple advantages of increased capability, lower heat rate and an increased supply of exhaust gas at nearly constant temperature.

Use of Combustion Gas in the Steam Generator

Several factors must be carefully assessed to determine the suitability of superposing a combustion topping unit on an existing steam power plant. These are:

(*a*) The quantities of combustion gas which can be used by a steam generator at a given load are a function of the size or capacity of the steam generator. Therefore, the size of the combustion topping unit is some function of the size of the steam generator and the concentration of air in the combustion gas mixture.

(*b*) The maximum recovery of energy from the gas-turbine exhaust gases can be achieved in a steam generator that for some reason, is not equipped with an air preheater. It is clear that if the temperature of the flue gas leaving such a unit is below that of the air entering the combustor of the gas-turbine plant more energy can be recovered in the steam generator than is possible in even a perfect regenerator.

(*c*) If the steam generator is equipped with an air preheater the energy recovery from the gas-turbine exhaust gases obviously cannot meet the level possible in *b*. Two limits exist. If gas-turbine exhaust gases are used exclusively then the maximum preheat temperature and maximum stack temperatures will be reached since the air preheater would not be used. The other limit is for normal operation with combustion air where the minimum preheat and stack temperatures are reached. Between these two limits lies an optimum condition which can be achieved by sending some air to the preheater to lower the stack temperature and mixing the preheated air with the gas-turbine exhaust gases to provide the combustion gas. The reduced air flow to the air preheater will result in a higher stack temperature than if the normal air flow were used. However the air temperature leaving the air preheater will approach the temperature of the flue gas entering the air preheater with reduced air flow. The optimum condition is reached when the difference between the rise in preheat temperature and the rise in stack temperature is a maximum. How large this difference will be is a function of the temperature of the gas-turbine exhaust gases, the temperature of flue gas entering air preheater and the amount of steam generator heat transfer surface in the air preheater.

(*d*) The effective preheat temperature is governed by the method of firing and the type of fuel used in the steam generator. The preheat temperature for stoker-fired units is generally limited to 300 F to minimize stoker maintenance, although some units have been operated successfully with preheat temperatures as high as 450 F. Since gas-turbine exhaust gases are rarely available at temperatures lower than 750 F a considerable quantity of tempering air would be required to prepare a combustion gas at 300 F. This condition would restrict severely the size of the gas-turbine plant. Under such circumstances a regenerator may be profitably used in the gas-turbine power plant to reduce the gas-turbine exhaust gases to a suitably low temperature.

In steam generators fired with pulverized coal there appears to be no limit to the preheat temperature other than the limitations imposed by the materials of the steam generator itself and the slagging properties of the coal. Smaller quantities of primary combustion gas are required for the mill dryers than with normal primary air since the temperature of the primary combustion gas

may be considerably higher. Since pulverizer exhausters are limited to inlet temperatures of 180 F the effective temperature of the total combustion gas, primary and secondary, is increased as the flow of primary combustion gas is reduced.

(*e*) Pulverized coals of higher moisture and sulfur content may be burned in an existing steam generator without installing additional pulverizer capacity or the danger of corrosive condensation in the air preheater. The high temperature of the gas-turbine exhaust gases used as primary combustion gas increases the capacity of the pulverizers and the higher flue gas temperatures leaving the air preheater lessen the danger of corrosion attendant upon condensation with high-sulfur fuels.

(*f*) The higher preheat temperatures possible when using combustion gas increase the furnace temperatures in the steam generator and the speed of the combustion reaction. A more complete combustion takes place with a decrease in the loss due to unburned combustibles in the flue gas. It is estimated that because of improved

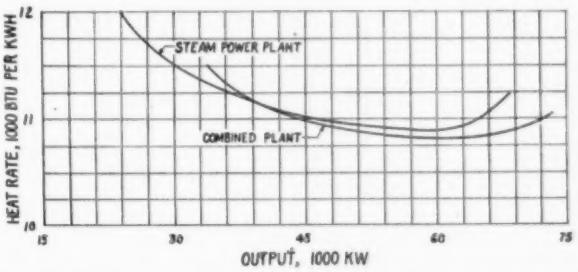


Fig. 4—Heat rates of combined and steam power plants

combustion conditions the same actual ratio of combustion gas to fuel may be employed as when using combustion air, even though the free-oxygen content of the combustion gas is lower.

Higher furnace temperatures increase the radiant-heat transfer rate. Therefore, increased capability in the steam power plant is possible if steam generator capacity is a limiting factor.

Application of the Combustion Topping Unit

In this section a combustion topping unit is superposed in theory on an existing steam power plant and the results are summarized.

The gas-turbine power plant consists of a compressor, combustor, gas turbine, generator, starting motor and necessary ductwork. The turbine exhausts directly to the steam generator at windbox pressure. The efficiencies of the gas-turbine power plant components are assumed to be as follows:

$$\eta_c = 0.830$$
$$\eta_t = 0.875$$
$$\eta_b = 0.980$$
$$\eta_g = 0.950$$
$$\eta_m = 0.980$$

where

η_c = adiabatic efficiency of compressor.
η_t = internal engine efficiency of gas turbine.
η_g = generator efficiency.
η_m = mechanical efficiency.
η_b = combustor efficiency.
W = weight rate of flow, lb per hr.
h = enthalpy, Btu per lb of fluid.
HHV = higher heating value of fuel, Btu per lb.

A compression ratio of 6 and a static pressure loss of 1.3 psia in the combustor are assumed. The gas-turbine inlet temperature is taken as 1400 F and the fuel is assumed to be Bunker C oil of the following gravimetric analysis.

$C = 84.0$
$H_2 = 12.5$
$O_2 = 1.2$
$N_2 = 1.7$
$S = 0.4$
Ash = 0.2
Moisture = Trace

The lower heating value is assumed to be 17,500 Btu per lb.

Combustion calculations yield the following gravimetric analysis for the gas-turbine exhaust gases.

$O_2 = 18.71$
$N_2 = 75.51$
$CO_2 = 4.14$
$H_2O = 1.51$
$C = 0.023$
$H_2 = 0.003$

The ratio of fuel to total air is calculated to be 0.01388.

Pertinent pressures, temperatures and weight rates of flow are given in the heat-balance diagram of Fig 2. The gross heat rate of the gas-turbine power plant in independent operation figures 19,180 Btu per kwhr when the net output is 5100 kw.

The turbine-generator is a 60,000-kw ASME-AIEE preferred standard unit with four extractions for feedwater heating. The steam generator is direct fired with pulverized coal and has a rated capacity of 650,000 lb per hr at 850 psig and 900 F. The heat transfer surface is so proportioned that the flue gas temperature entering and leaving the air preheater are 750 F and 405 F, respectively, at rated load.

The characteristics of the coal are assumed to be as follows on an "as-received basis."

Ultimate Analysis		*Proximate Analysis*	
C	= 77.29	Volatile matter	= 20.61
H_2	= 4.59	Moisture	= 3.39
O_2	= 5.61	Fixed carbon	= 66.53
N_2	= 1.73	Ash	= 9.47
S	= 1.31	HHV = 13,620 Btu per lb.	
Ash	= 9.47	Grindability = 95 Hardgrove	

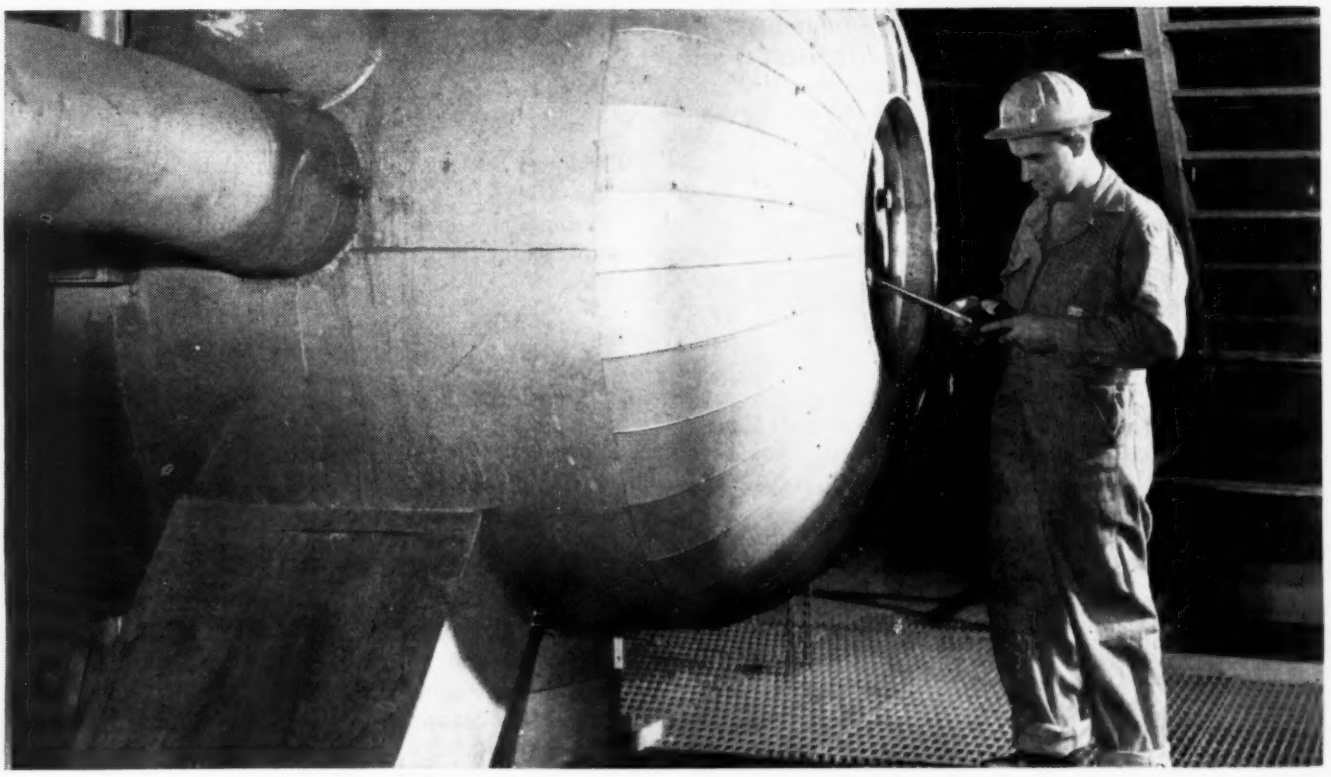
Air is assumed to enter the air preheater at 80 F and 70 per cent relative humidity.

A typical calculated heat balance for the combined plant is shown in Fig 2 and the performance of the steam generator when using combustion gas is compared with the performance when using combustion air in Fig. 3. The heat rates of the combined plant and the steam power plant in independent operation are compared in Fig. 4. It will be observed that the heat rate curves intersect at a reduced load on the combined plant. Since the net output of the gas-turbine plant is constant this means that below a certain load on the steam power plant it is unprofitable to employ the combustion topping unit.

(*Continued on page 58*)

CHEMICAL CLEANING PROVED MORE EFFECTIVE IN BOILER TEST

DOWELL method showed greater efficiency by 4.5% in utility company comparison



Perhaps the most convincing way of demonstrating the advantages of one method of cleaning over another is to conduct a comparative test.

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Method for Cleaning Regenerative Type Air Preheaters—Part II

By JOSEPH WAITKUS*

The first article of this series, which appeared in August, discussed broadly improved equipment and procedures for cleaning this type of air preheater and specifically the comparative merits of different blowing media. The present article continues with a discussion of nozzle pressures, drainage, frequency of blowing, and observations on cleaning action. The third, and final article, to appear in October, will take up washing the heating surface, water requirements, and the equipment required.

THE now obsolete multi-jet soot blower was limited to a maximum steam pressure of 175 psig at the nozzle pipe. Attempts to increase the pressure were ruled out due to the damaging effect on radial seals and heating surface. It must be admitted, however, that the multi-jet arrangement was never directed against the improved design radial seals fabricated of heavy gage material and into tightly packed heating surface. Actually, the developments in cleaning equipment paralleled those in radial seal designs and heating surface installation technique.

A question now arises as to the reason for changing from the multi-jet to the single or dual jet cleaning device. What is the advantage? Why not just increase the pressure in the multi-jet arrangement, apply seals of improved design, and pack the heating surface more tightly?

The change was brought about basically by the fact that with a solid jet of cleaning medium, it was possible to obtain a higher cleaning effiicency. Coupled to this is the additional fact that a wider range of safe blowing pressures was made available to meet difficult or emergency deposit accumulations. It was obvious for a long time that the multi-jet arrangement was not effective because the energy was divided into a number of blasts, none of which could bring sufficient action to bear on the deposit at any particular location. Increasing the pressure to improve the results served only to increase the steam consumption and endangered the rotor seals because the impact was delivered over the full length of the radial seal members.

For the single and dual nozzle cleaning devices, the recommended pressure is 200 psig for steam, either saturated or superheated, and 180 psig for compressed air. The latter recommendation is based on the higher density of the medium. Pressures above and below the recommended level can be used if certain conditions are observed and recognized.

There is no point in blowing with a higher pressure than necessary. Every effort should be made to lower the blowing pressure in accordance with the operating results desired. It will save unnecessary wear and tear of the equipment, and in addition will reduce the quantity of cleaning medium consumed. Some installations are obtaining satisfactory results with steam at 100 psig.

There is, however, a limit to increasing the blowing pressure. The recommendation is not to exceed 250 psig for steam and 200 psig for air as regular practice. Pressures up to 600 psig have been reported, but they are rare and usually the result of carelessness or an attempt to overcome an emergency condition created by extremely heavy and stubborn deposits on the heating surface. The effect on the deposits was in most cases reasonably good, but when the high pressure was used for an extended period, the radial seals and heating surface were badly damaged.

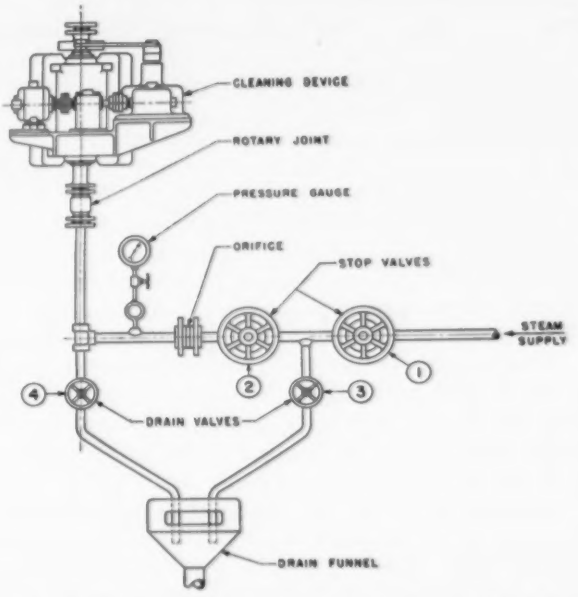


Fig. 11—Recommended piping arrangement for blowing with steam

It is customary to start with the recommended pressure and adjust it gradually, as results indicate necessary, by changing the size of the orifice shown in the typical steam piping arrangement in Fig. 11.

When increasing the pressure, it should be done with precise control and observation of the effect on deposits and equipment. Obviously, increasing the pressure just to tear loose a stubborn deposit accumulation without considering the possible effects on the operating life of

* Assistant to Technical Manager, The Air Preheater Corp., Wellsville, N.Y.

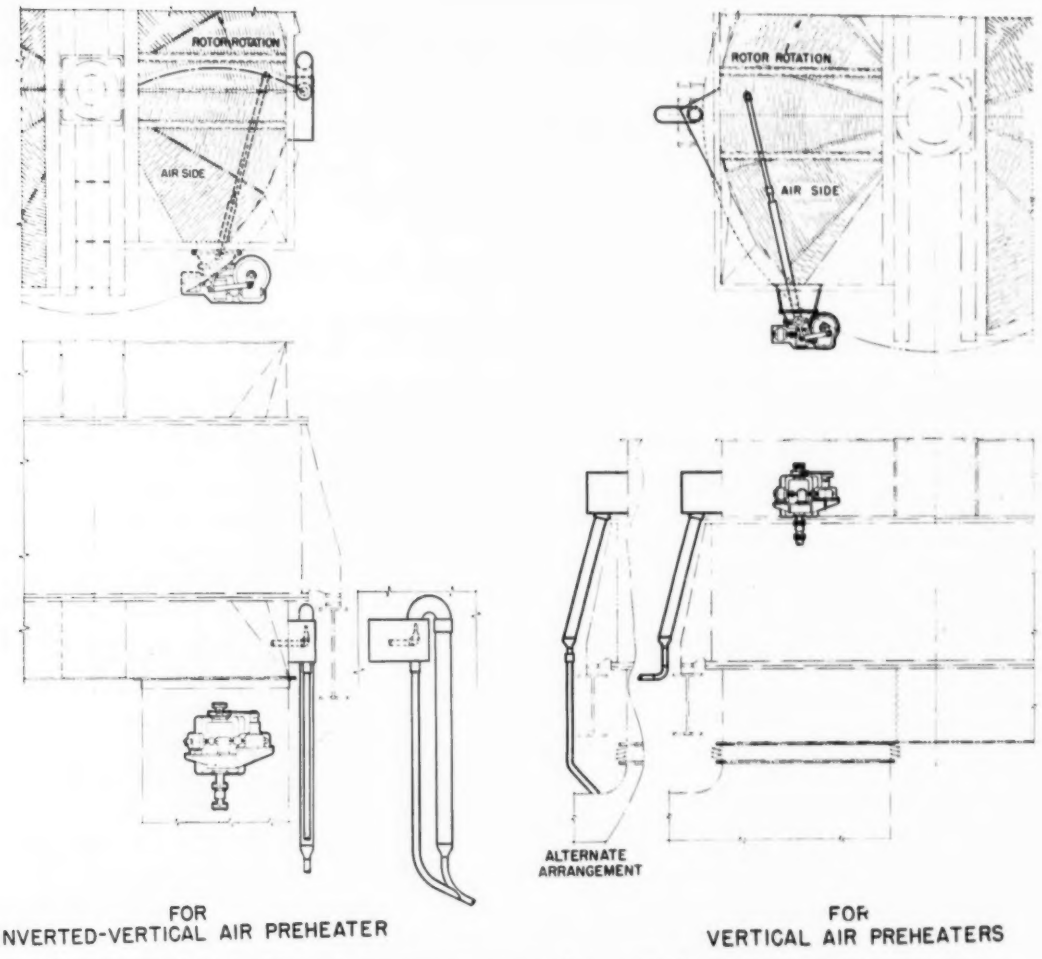


Fig. 12—Typical built-in drain arrangements for vertical and inverted air preheaters

seals and surface can be a serious oversight. It is recognized, of course, that the period over which the high pressure blowing is used influences the final results. For emergency purposes high pressure blowing at intervals for a few days may not show damaging effects, depending on the condition of the equipment. The seals may be of advanced design, but, if thinned by corrosion, they will not withstand the impact of the high pressure cleaning jet. The heating surface too may be thinned by corrosion and unable to take the impact of the jet. If the heating surface is loosely packed in the air preheater rotor the high pressure jet may vibrate it intensely and reduce it to fragments in a very short time.

As pointed out above, caution must be exercised when increasing the pressure and it is, therefore, recommended that it be carried out in increments of 10 to 20 psig with a reasonable operating period at each increment to determine the effectiveness of the increase. This procedure is recommended when it is found desirable to revise the routine blowing practice between the limits of 200 and 250 psig for steam, and 180 and 200 for air. For emergency purposes, the increments can be increased to between 50 and 75 psig with the understanding that it will only be for a short period and regarded as an experiment. A new orifice will be required when it is decided to return to the recommended pressure.

Adequate means for draining the lines and proper use of the equipment is of the utmost importance. The recommended equipment is illustrated in typical arrangement in Fig. 11. The need for attention to drainage applies to any of the cleaning mediums whether it be saturated or superheated steam or air. For steam a special procedure has been established which can be stated as follows, using designations employed in Fig. 11:

At Start:

Valves 1 and 2 should be closed.
Valves 3 and 4 should be open.

To Blow:

Open valve 1 and drain lines thoroughly for a period assuring complete removal of wet steam and condensate from lines ahead of cleaning device.
Open valve 2.
Close valves 3 and 4, and start operating the cleaning device.

After Blowing:

Follow the above in reverse order.

The built-in drain hopper arrangements shown in Fig. 12 have been included in a few vertical-type air preheaters equipped with a single-nozzle cleaning device. One arrangement is for standard vertical units with the cleaning jet discharging into the heating surface below, and the other is for inverted vertical units where the cleaning jet discharges upwards. A large pipe, or plenum chamber, is provided into which the nozzle initially discharges the steam and any moisture entrained in it. As soon as

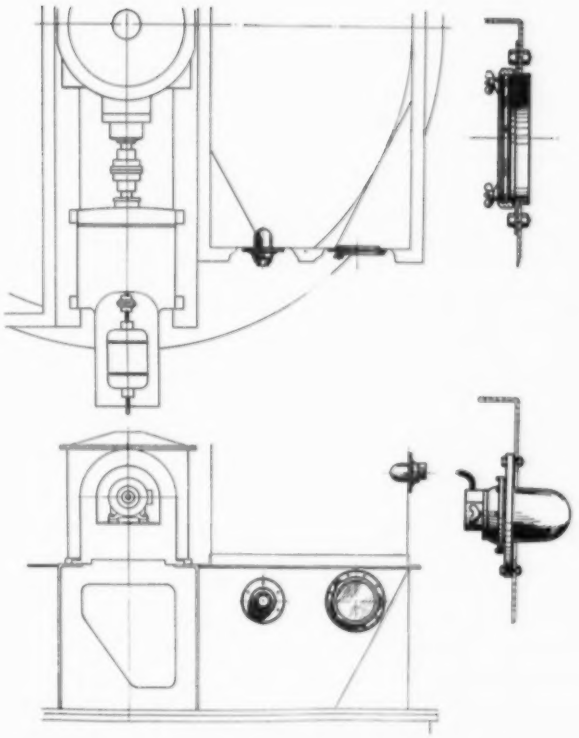


Fig. 13—Arrangement of vapor-proof light and observation port in air inlet

the jet appears clear of moisture, the cleaning device can be placed in operation and the nozzle moved over the heating surface to perform the cleaning action. It is a simple and effective arrangement, saving the expense of drain valves required in the conventional piping arrangement shown in Fig. 11.

There is one important condition, however, that must be observed to make this type of drain effective: the hopper discharge must be free blowing and the piping must be at least 2 in. pipe size with long-radius bends and gradual changes in cross-section.

One suggestion which appears to have some merit is the alternate arrangement in Fig. 12 showing the hopper connected into the air outlet duct of the air preheater. This allows a more direct and free passage for the steam and moisture. It is actually a moisture bypass around the heating surface of the air preheater. But if the cleaning device is installed on the gas side, which is gaining popular approval currently, this alternate drain scheme is not desirable. Obviously, with the flow of gases in the direction of the cold end, any water drained into the hot end through such a bypass would only return to wet the heating surface.

A steam separator close to the cleaning device has been of some help in the removal of entrained moisture and condensate. However, most of these have not been sufficiently effective to give the desired results. The need for some form of free draining or blowing, such as described above, still remains important. Observation of the condition of the cleaning jet is the only safe indication that the cleaning medium is somewhere near the dry state.

Frequency of Blowing

How often to blow is a question that is often raised. Obviously, there is no use blowing more frequently than necessary. The results will not justify it; it is a waste of cleaning medium; and, it subjects the equipment to an undue amount of wear. It is considered, therefore, good practice initially to adopt a procedure of blowing once every 8 hr. If, after thorough examination of the

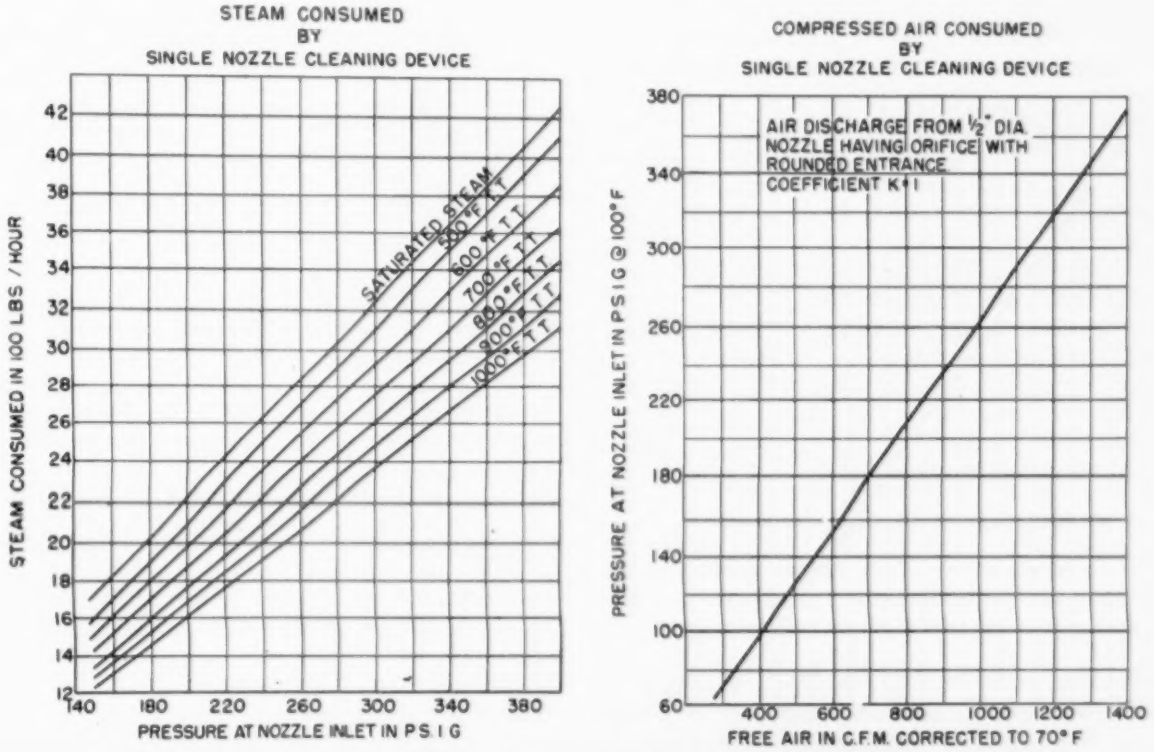


Fig. 14—Steam and compressed air consumed by single nozzle cleaning device

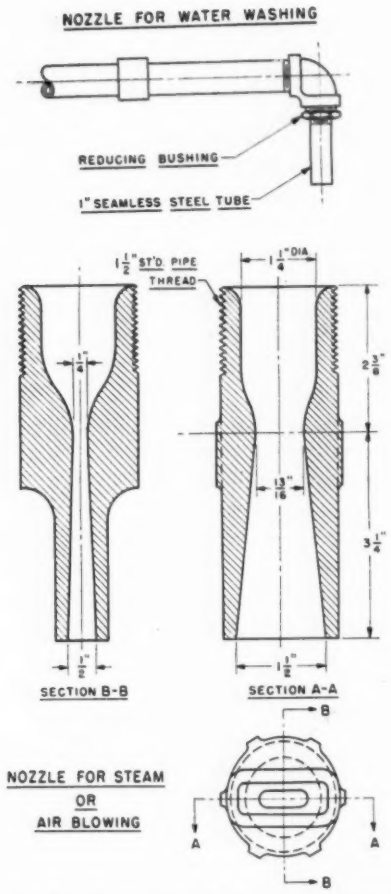


Fig. 15—Nozzles for steam or air blowing and water washing

condition of the heating surface, a change in blowing frequency seems desirable, it is recommended the change be carried out gradually. Experience seems to show that if blowing at 8-hr intervals is not adequate, increasing the frequency rarely improves the results. The nature of the deposit and the rate of accumulation may be such as to require instead a stronger cleaning jet action by increasing the blowing pressure or a washing of deposits to restore the heating surface to satisfactory operating condition. The exception is in the case of an emergency created by an accumulation of deposits which threatens to force the unit out of service. In such a case, more frequent blowing may serve to give some relief until a convenient outage can be scheduled for other measures, such as washing.

Due to lack of time for investigative work and motivated by an intense desire to avoid a forced outage due to excessive accumulation of deposits, the tendency is to over-blow the air preheater. Very often, it will be found that reducing the frequency of blowing gives just as good results as the 8-hr. schedule.

Observing the Cleaning Action

Ability to observe the action of the cleaning device with the preheater in operation is considered essential to effecting changes discussed above. By installing the cleaning device in the air inlet of the air preheater, it is easy to provide an observation window or porthole and a light to illuminate the interior of the duct close to the heating surface. Fig. 13 illustrates the type of observation port and light usually provided.

General Facts

The quantity of steam, saturated or superheated, and compressed air consumed by a single-nozzle cleaning device is shown graphically in Fig. 14, based on pressures and temperatures at the nozzle inlet. Double the quantities for the dual nozzle cleaning device.

A cross-section through the nozzle adopted as a standard for either steam or air blowing is illustrated in Fig. 15. The throat and discharge opening has the form of a slot with an area equivalent to a $^1/_2$ in. diameter circle. It produces a fan-shaped jet and with the nozzle outlet about 12 in. from the edge of the heating surface, the jet covers a width of approximately 4 in. By overlapping in the course of the movement of the nozzle over the heating surface, complete and uniform coverage of the area is obtained.

The nozzle for cleaning medium temperatures below 750 F is made of cast iron. Above 750 F the nozzle requires an alloy suitable for elevated temperatures.

The long axis of the nozzle opening is always at right angles to the width of the heating element sheets. This causes the cleaning jet to straddle several sheets and passages, and avoids concentrating the jet into one passage, as would be the case if the long axis were parallel to the width of the sheets. This point is best illustrated by Fig. 16. When the cleaning jet is parallel to the sheets, an intense vibration of the sheets is created which is likely to damage the heating surface and break it into fragments. With the jet at right angles to the sheets, there is practically no vibration because of the uniform pressure on both sides of the sheets. For the dual nozzle design, it is impossible to avoid some vibrating action of the cleaning jets. The nozzles are therefore set so that

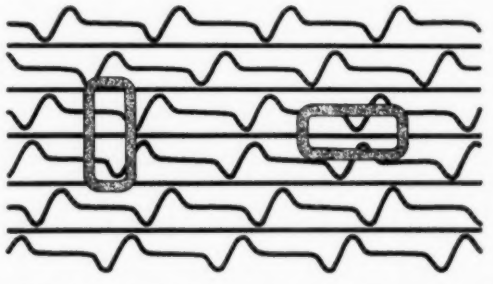


Fig. 16—Position of nozzle opening with respect to heating surface

they are at right angles to the sheets at the periphery and center of the rotor, the two points where the nozzles move the slowest. At other parts of the rotor, the nozzles move comparatively faster, and although the nozzle openings will be parallel with the sheets, the period is so short that it has practically no damaging effects.

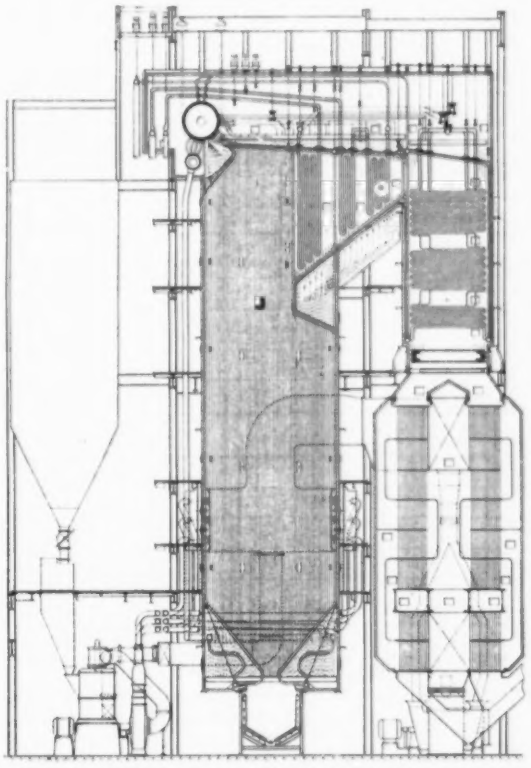
Conclusion

As a conclusion to the first phase of the subject of cleaning the regenerative type air preheater, it might be stated that developments in equipment and procedure, insofar as steam and air cleaning is concerned, have kept pace with the demands on the application of this type of air preheater and the advances in design and operation of steam generating units.

(The concluding section of this series to appear in October, will discuss washing the air preheater.)

Hennepin Station of Illinois Power Company

The cover photograph of this issue shows the new Hennepin Station of the Illinois Power Company, located on the Illinois River some twenty miles south of La Salle. This plant which was formally put in service on June 19 is the third to be built in the postwar period and construction has already started on a fourth, the Vermillion Station, near Danville, Ill. The first was the Havana Station[1] at Havana, Ill., the initial unit of which was placed in service during August 1947. Shortly thereafter there was added to the system the Wood River Station situated about 100 miles distant on the east bank of the Mississippi between Alton and Wood River. In many respects it was similar to Havana which now



Section through C. E. Boiler at Hennepin

has five 50,000-kw units whereas Wood River has three 50,000-kw and one (the latest) 100,000-kw unit. The first unit at Hennepin is rated at 75,000-kw. Thus in the relatively short period of six years the Company's installed generating capacity has increased fifteen-fold.

Steam conditions at Hennepin are 1500 psig and 1005 F at the superheater outlet with reheat to the same temperature. Initially, Illinois coal of around 10,400 Btu per lb, 10.6 per cent ash and 1960 F ash-fusion temperature will be burned, although the boiler is designed to handle natural gas or oil, if either should later become desirable. The coal, which is normally delivered by barge, is pulverized by three Raymond bowl mills and tangentially fired by tilting burners having a control range from 300,000 to 525,000 lb of steam per hour. Further steam temperature control is provided by desuperheater spray. The unit is provided with both an economizer and a tubular type air heater.

[1] For description, see COMBUSTION of December 1947.

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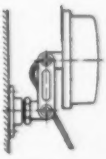

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90° Reducing	2"x¾" to 6"x5"		....	....	....	....
90° Short Radius	1"-30"	1½"-30"	....	....	....	....
45° Long Radius	½"-42"	¾"-42"	1"-12"	¾"-8"	4"-24"	¾"-12"
RETURNS 180° Long Radius	½"-30"	½"-30"	1"-12"	2"-8"	4"-24"	¾"-12"
180° Short Radius	1"-30"	1½"-30"	....	....	....	....
180° Ex. Long Radius	1"-2½"	1"-2½"	....	....	....	....
TEES — Straight	½"-30"	½"-30"	½"-12"	½"-8"	....	....
Reducing Outlet	½"-30"	½"-30"	¾"-12"	¾"-8"	....	....
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CAPS	¾"-36"	¾"-36"	1"-12"	1"-8"	....	....
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LATERALS — Straight	1¼"-24"	1¼"-24"				
Reducing	1¼"-24"	1¼"-24"				
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Acid Regeneration of Cation Exchangers*

By F. K. LINDSAY

The National Aluminate Corp.

Data are presented showing the importance of application techniques in the use of both sulfuric and hydrochloric acids as regenerants for cation-exchange resins; also comparisons between the two acids are given which show the water quality and cation-exchange capacity obtained with each.

THE acids most commonly used for the regeneration of cation-exchangers in hydrogen-cycle operation are sulfuric acid and hydrochloric acid.

There are two factors that are largely responsible for the choice of acid to be used in any operation. First, the availability of the acid under consideration, and second, the comparative cost of the acids for the particular installation involved. Sulfuric acid is most commonly used in large installations, for in most parts of the country it is more economical. Hydrochloric acid is generally selected for the smaller installations for its greater ease of application, as well as for the higher exchange capacities that can usually be obtained from its use.

In the application of sulfuric acid for the regeneration of high capacity cation-exchange resins, the ratio of each individual cation to the total cations in the raw water is very important. If there is a large preponderance of calcium in the influent, there will be the same relative preponderance in the exhausted resin bed. Because of the much greater capacity of the current polystyrene resins as compared to the older, low-capacity hydrogen exchangers, the possibility of encountering calcium sulfate precipitation during regeneration is greatly increased. If, on the other hand, there is a high percentage of sodium in the raw water, the sodium will predominate in the exhausted bed and if not thoroughly eliminated by the regeneration process, will result in sodium leakage during the operating cycle that follows.

Cation leakage has generally been considered as the escape of a cation such as sodium, through the resin bed without being removed. This is actually incorrect, as the leakage of cations during the operation cycle is entirely due to failure to eliminate completely the cations from the resin bed during the regeneration and rinsing operation. The exchange of hydrogen ions produced in the upper part of the bed with the ions left in the lower part of the bed causes the leakage. The degree of leakage is influenced by the anion content of the raw water.

To avoid calcium sulfate precipitation, it has been the practice to apply the sulfuric acid at a concentration of 2 per cent or less and not exceed this concentration throughout the entire regeneration process. This procedure, however, is not productive of the best results when regenerating the high-capacity polystyrene resins.

Members of our research staff have reported that the sulfuric acid regeneration is most effectively carried out by using a "stepwise regenerant addition" in which the regenerant concentration and/or regenerant flow rate are varied (1). By selecting the proper technique the dosage can be reduced to a minimum consistent with the exchange capacity and quality of effluent desired. In general, optimum results are obtained when the highest possible sulfuric acid concentration contacts the resin bed at the slowest possible flow rate without incurring calcium sulfate precipitation. In other words, on waters high in sodium content the rate of flow of regenerant

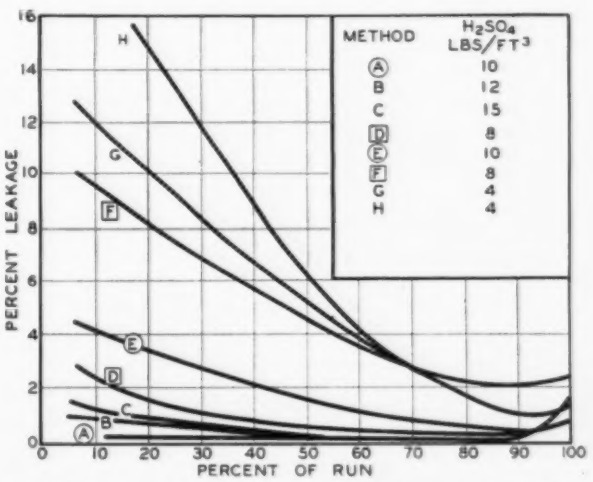

Fig. 1—Water quality vs. regenerant dosage and method of regenerant application (deionizing water shown in Table 1—high capacity polystyrene resin)

application may be as low as 0.4–0.5 gpm per cu ft, while on high-calcium-bearing waters, the regenerant may be applied at rates as high as 2.0 gpm per cu ft.

The curves presented in Fig. 1 illustrate the effect of variations in the technique of sulfuric acid application, as well as variations in the amount of regenerant employed, on treated water quality. This work was carried out on a water supply that is very difficult to deionize as shown in Table 1. All values are expressed in parts per million as $CaCO_3$ and per cent. The percentages of the individual constituents present are shown because these are the determining factors in the selection of the proper regeneration procedure. These percent-

*Presented at the American Power Conference at Chicago, March 27, 1953.

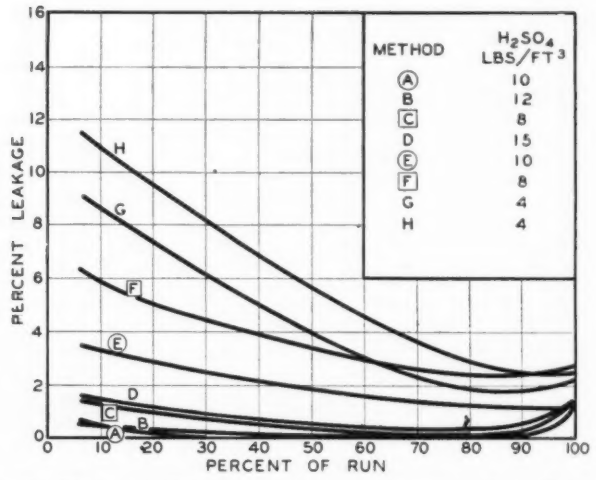

Fig. 2—Water quality vs. regenerant dosage and method of regenerant application (deionizing water shown in Table 2—high capacity polystyrene resin)

ages, as well as the total ion concentration, govern the water quality obtainable.

TABLE 1

Cations (as $CaCO_3$)	Ppm	%	Anions (as $CaCO_3$)	Ppm	%
Calcium	171	33	Bicarbonate	0	0
Magnesium	85	17	Sulfate	171	33
Sodium	257	50	Chloride	342	67
Total cations	513		Total anions	513	

The cation leakage was determined by deionizing the cation effluent in each case. Regeneration Methods D and F (see Fig. 1) both employed an 8 lb per cu ft dosage of sulfuric acid. Method D not only produced a much better water quality, but in addition 21 per cent more exchange capacity. In Method D the acid was added "stepwise" with portions applied as 2-, 4-, 6- and 8-per cent solutions respectively, all at a flow of 0.5 gpm per cu ft of exchanger. In contrast, all of the regenerant in Method F was applied as a 4-per cent solution. In order to avoid calcium sulfate precipitation, this solution was all passed through the exchanger bed at a rate of 2.4 gpm per cu ft. Methods A and E likewise employed equal regeneration dosages, i.e., 10 lb per cu ft. The superior water quality obtained from Method A is readily seen. In addition, this procedure resulted in 26 per cent more exchange capacity than Method E. In Method A, stepwise additions of 2-, 4-, 6- and 8-per cent solutions were made, all at a flow rate of 0.5 gpm per cu ft while in Method E, the concentration of the regenerant was varied over the range of from 2 to 8 per cent and the flow rate of regenerant addition was also varied from 0.6 to 2.0 gpm per cu ft.

Fig. 2 illustrates the results obtained in applying varying regeneration procedures to a second water supply shown in Table 2. All values are expressed in parts per million as $CaCO_3$ and per cent.

TABLE 2

Cations (as $CaCO_3$)	Ppm	%	Anions (as $CaCO_3$)	Ppm	%
Calcium	171	33	Bicarbonate	257	50
Magnesium	85	17	Sulfate	85	17
Sodium	257	50	Chloride	171	33
Total cations	513		Total anions	513	

Methods C and F employed the 8 lb per cu ft dosage, whereas methods A and E used a 10-lb dosage. In addition to superior water quality, Method C produced 22 per cent more ion-exchange capacity than Method F, and Method A, 26 per cent more capacity than Method E. Methods C and A employed stepwise additions of 2-, 4-, 6- and 8-per cent solutions at a rate of 0.5 gpm per cu ft while Method F applied 4 per cent sulfuric acid solution at a rate of 2.4 gpm per cu ft and Method E varied both the acid concentration and the flow rate of regenerant application. The details of the regenerant methods referred to in Figs. 1 and 2 are summarized in Table 3.

In applying stepwise additions of increasing concentrations of sulfuric acid to polystyrene cation-exchangers of medium exchange capacity, the quality of water produced is very little different from that obtained when using a regenerant concentration of 2 per cent acid only. The stepwise procedure, however, is capable of producing much higher ion-exchange capacity for a given dosage. Fig. 3 compares the two regenerant procedures

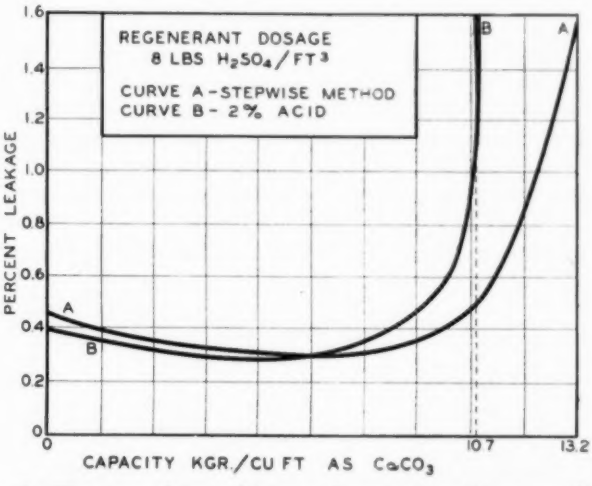

Fig. 3—Water quality and ion-exchange capacity vs. method of regenerant application (deionizing water shown in Table 1—medium capacity polystyrene resin)

TABLE 3

Method	Bed Depth, in.	H_2SO_4, lb per cu ft	Method of Application: Lb at 2%	Rate*	Lb at 4%	Rate*	Lb at 6%	Rate*	Lb at 8%	Rate*
A	60	10	2	0.5	2	0.5	3	0.5	3	0.5
B	30	12	2	0.5	2	0.5	4	0.5	4	0.5
C	60	15	2	0.6	2	1.0	3	1.5	8	2.0
D	30	8	2	0.5	2	0.5	2	0.5	2	0.5
E	60	10	2	0.6	2	1.0	3	1.5	3	2.0
F	30	8	...	...	8	2.4	...	...	...	...
G	30	4	2	0.5	2	0.5	...	...	...	...
H	60	4	1.5	1.3	1.25	1.3	0.75	1.3	0.5	1.3

* Regenerant flow; gpm per cu ft.

referred to in treating the water described in Table 1. The stepwise procedure (represented by Curve A) developed 24 per cent more capacity than was obtained from the use of 2 per cent acid only (Curve B).

Fig. 4 illustrates these same general findings when treating the water shown in Table 2 with medium capacity polystyrene cation resin. Here again the capacity obtained by use of a stepwise procedure (Curve A) was 23 per cent greater than that resulting from the use of 2 per cent acid only (Curve B).

In industrial installations, the stepwise procedure developed in the laboratory often gives way to a "progressive" procedure because of greater simplicity of application. Both acid concentration and rate of regenerant application are gradually increased by means of blending devices in use, or the acid concentration only is gradually increased and applied at a fixed flow rate. The acid pumped from the storage or measuring tank may range in concentration from 93 per cent H_2SO_4 (66 deg Bé) down to 10 to 12 per cent, depending upon the choice of blending system.

Regeneration procedures in use at a large western utility offer an excellent comparison with data reported in Fig. 2. The analysis of the water being deionized with a two-step installation consisting of two cation-exchanger units, a common degassifier, and two anion units is shown in Table 4. All values are expressed in parts per million as $CaCO_3$ and per cent.

TABLE 4

Cations (as $CaCO_3$)	Ppm	%	Anions (as $CaCO_3$)	Ppm	%
Calcium	250	43	Bicarbonate	200	35
Magnesium	90	16	Sulfate	317	54
Sodium	241	41	Chloride	64	11
Total cations	581		Total anions	581	

Each cation-exchanger contains 315 cu ft of high-capacity polystyrene resin, with 60-in. bed depth. The regeneration technique used at this plant is somewhat limited by the physical sizing of certain of the equipment which was originally installed for operation with recycle of the regenerant. This has permitted the progressive application of gradually increasing concentrations of sulfuric acid with very gratifying results. Consideration was given to the water analysis as it affects the ion content in the exhausted bed and to the regenerant dilution that would occur in the cation unit itself. A typical regeneration cycle is plotted in Fig. 5. The cation-exchanger was backwashed 15 min with raw water prior to the downflow introduction of the regenerant. Acid concentration is adjusted so that the concentration of the mixed constituents leaving the cation unit gradually increases from 2 to 8 per cent. The flow rate varies from 0.4 to 2.0 gpm per cu ft. With slight modification of the mechanical equipment, the contact between the acid and exchanger bed can be extended by reducing the regenerant flow rate to 0.8–1.0 gpm per cu ft as the maximum flow.

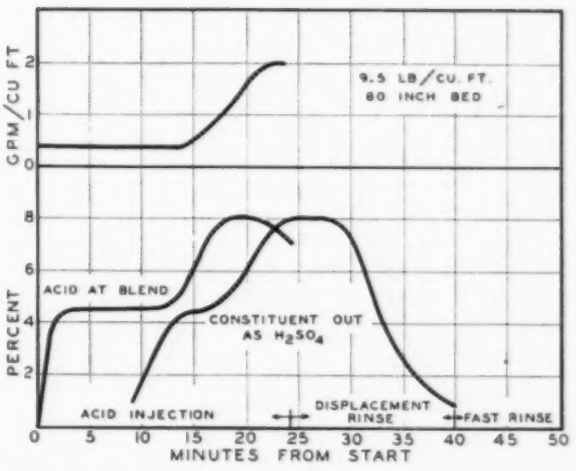

Fig. 5—Regeneration of high-capacity polystyrene resin in unit operation of a western utility. 9.5 lb of H_2SO_4 per cu ft with 60 in. bed depth

Inasmuch as the effluents from the two cation-exchangers are blended for passage through the degasifier before going to the anion-exchangers and ultimately to storage, it was necessary to set up a test column and deionize the cation effluent without benefit of degasifying in order to evaluate the performance of the cation-exchangers independently. A cycle depicting the analysis for water quality obtained in this way is plotted as Curve A in Fig. 6. The range of water quality during two days

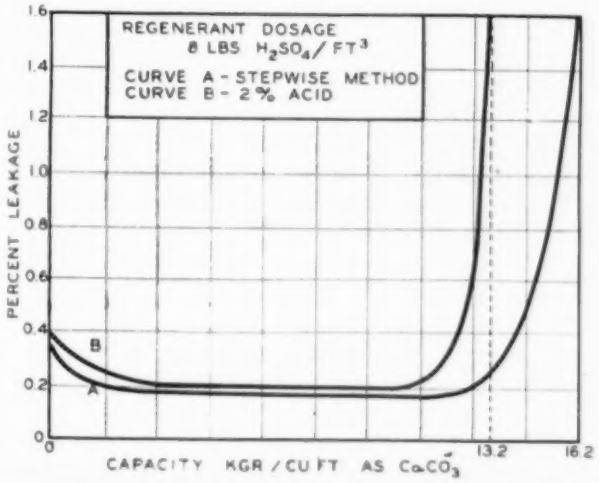

Fig. 4—Water quality and ion-exchange capacity vs. method of regenerant application (deionizing water shown in Table 2—medium capacity polystyrene resin)

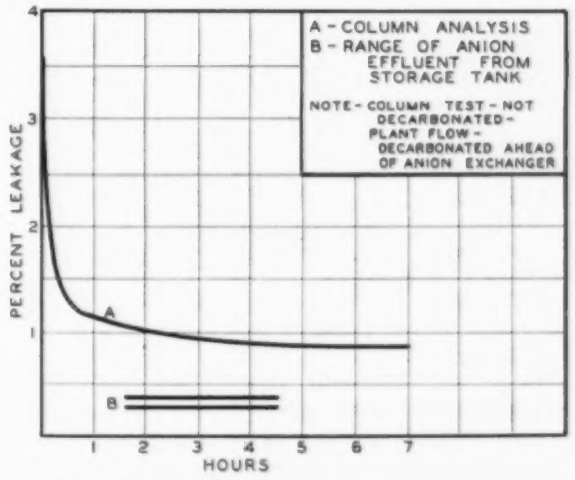
A - COLUMN ANALYSIS
B - RANGE OF ANION EFFLUENT FROM STORAGE TANK
NOTE - COLUMN TEST - NOT DECARBONATED - PLANT FLOW - DECARBONATED AHEAD OF ANION EXCHANGER
PERCENT LEAKAGE
HOURS

Fig. 6—Deionized water quality using high-capacity polystyrene cation-exchange resin at a western utility location

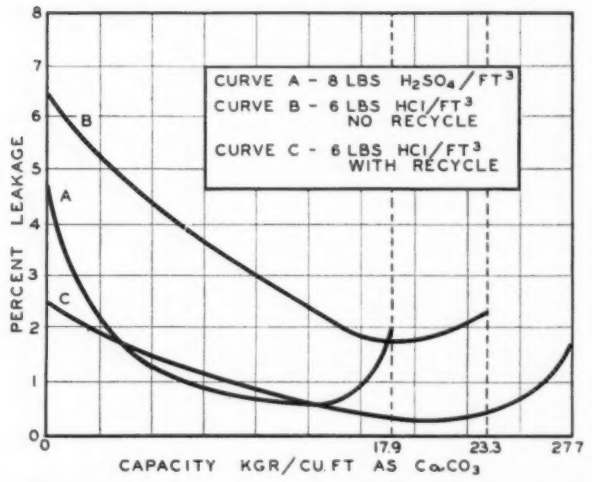

Fig. 7—Water quality and capacity. Sulfuric acid vs. hydrochloric acid (deionizing water shown in Table 1. High-capacity polystyrene resin)

of testing at this plant delivered from the storage tank is shown as Curve B. The cation-exchangers are operated to break-through of an anion-exchanger at which time an entire battery is removed from the line and regenerated. Under the operating conditions existing here, the high-capacity polystyrene cation-exchanger is performing at an exchange capacity of 20.5 kgrs per cu ft on a regenerant dosage of from 9 to 10 lb per cu ft.

Although, as pointed out in the introduction to this paper, it is more costly to apply hydrochloric acid as a regenerant than sulfuric acid, there are applications where the use of hydrochloric acid is justified. Fig. 7 compares the results in water quality and ion-exchange capacity obtained from the use of these two regenerants on an "equivalent hydrogen" basis, in the regeneration of a high-capacity polystyrene resin when treating the difficult test water shown in Table 1. This water contained 513 ppm of soluble salts with no bicarbonate alkalinity present. This same figure illustrates the improvement in water quality and ion-exchange capacity obtainable from the recycling of approximately 25 per

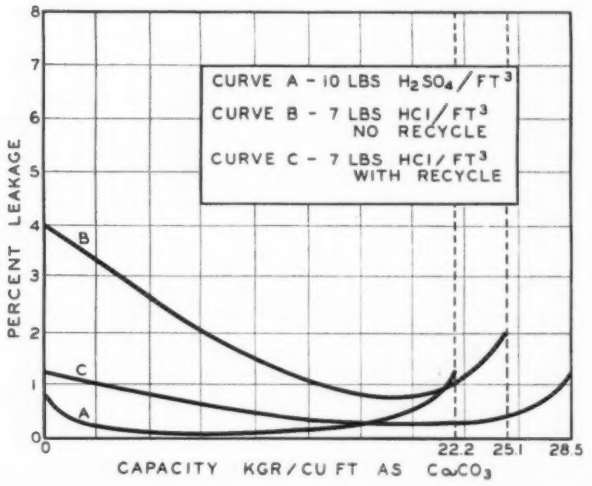
CURVE A - 10 LBS H_2SO_4/FT³
CURVE B - 7 LBS HCl/FT³ NO RECYCLE
CURVE C - 7 LBS HCl/FT³ WITH RECYCLE
PERCENT LEAKAGE
CAPACITY KGR/CU FT AS $CaCO_3$
22.2
25.1
28.5

Fig. 8—Water quality and capacity. Sulfuric acid vs. hydrochloric acid (deionizing water shown in Table 1. High-capacity polystyrene resin). Higher regenerant dosage.

cent of the hydrochloric acid used. Fig. 8 illustrates a similar comparison in which higher dosages of the two regenerants were used. Table 5 gives the ion-exchange capacities of acid consumed per kilograin of cations removed from the use of the two regenerants as applied in Figs. 7 and 8.

TABLE 5

Regenerant	Lb per cu ft	Capacity kgr as $CaCO_3$	Lb of acid per kgr
Fig. 7:			
H_2SO_4	8	17–18	0.44
HCl	6 (100 per cent acid), no recycle	22–23	0.26
HCl	6 (100 per cent acid), with recycle	26.5–27.5	0.22
Fig. 8:			
H_2SO_4	10	21–22	0.45
HCl	7 (100 per cent acid), no recycle	24–25	0.28
HCl	7 (100 per cent acid), with recycle	27.5–28.5	0.25

Fig. 9 illustrates the water quality produced and the ion-exchange capacity obtained from the use of the two regenerants on an "equivalent hydrogen" basis when treating the water shown in Table 2. While this water

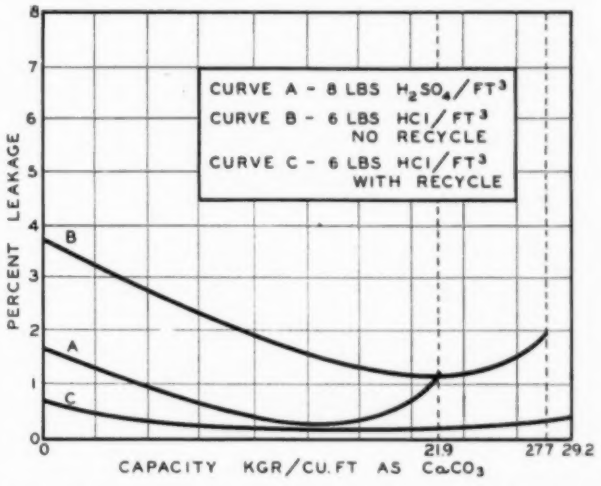

Fig. 9—Water quality and capacity. Sulfuric acid vs. hydrochloric acid (deionizing water shown in Table 2. High-capacity polystyrene resin)

contained the same concentration of soluble solids as that present in the test water, Table 1, it had a bicarbonate alkalinity equal to 50 per cent of the total anions. By comparing Figs. 7 and 9, it will be noted that the same acid dosages produced better water quality and greater capacity in the handling of the test water of Table 2 than was obtained in treating that of Table 1. Table 6 gives the exchange capacities and regenerant consumption resulting from equivalent acid dosages in treating the test water of Table 2.

TABLE 6

Regenerant	Lb per cu ft	Capacity, kgr as $CaCO_3$	Lb of acid per kgr
H_2SO_4	8	21–22	0.36
HCl	6 (100 per cent acid), no recycle	27–28	0.21
HCl	6 (100 per cent acid), with recycle	28–29	0.20

An examination of the results obtainable from the use of hydrochloric acid without recycle, as reported in Curve B, Figs. 7, 8 and 9 suggested that this regenerant

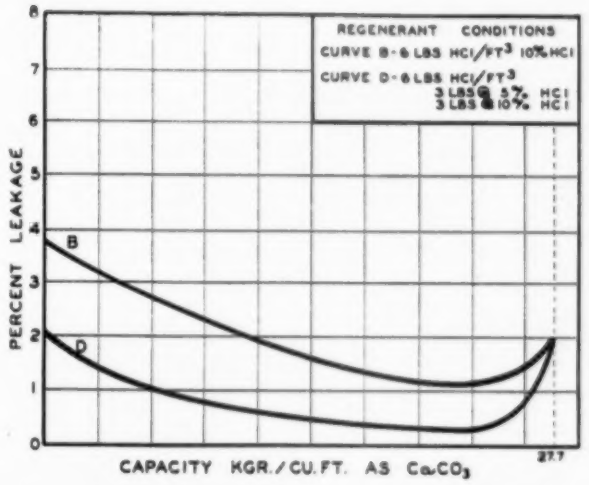

Fig. 9A—Water quality and capacity. Hydrochloric acid, 10-per cent solution vs. hydrochloric acid, 5-per cent solution and 10-per cent solution (deionizing water shown in Table 2. High-capacity polystyrene resin)

had not been effectively applied for the elimination of sodium from the cation-exchanger bed, as indicated by the resulting treated water quality. In each of the three instances reported, the hydrochloric acid was applied as a 10-per cent solution by weight. To eliminate the sodium more completely from the cation-exchanger bed, and subsequently to improve water quality, work was carried out in which part of the regenerant acid was applied as a more dilute solution, 5 per cent, the balance being as a 10-per cent solution. The results of this work are shown in Fig. 9*A*. Water quality and ion-exchange capacity obtainable from the application of hydrochloric acid as a 10-per cent solution are compared with that resulting from the use of half the regenerant as a 5-per cent solution and half as a 10-per cent solution. High-capacity polystyrene resin was employed for treating the water shown in Table 2. Curve B in Fig. 9*A* is therefore the same as Curve B in Fig. 9. By reducing the acid concentration for part of the regenerant applied, water quality comparable to that resulting from the use of sulfuric acid, Curve A, Fig. 9, was obtained.

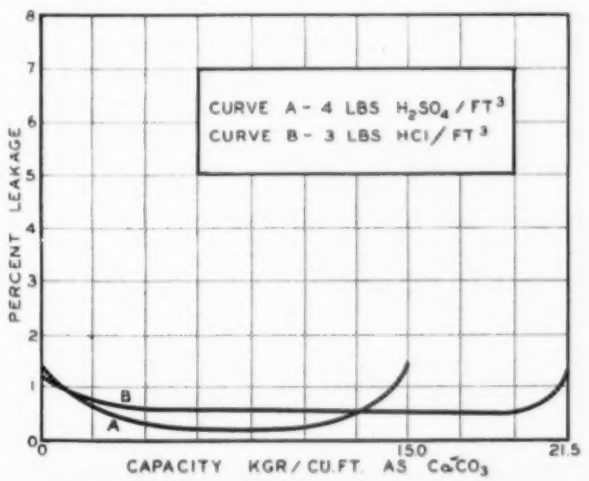

Fig. 10—Water quality and capacity. Sulfuric acid vs. hydrochloric acid (deionizing Lake Michigan water. High-capacity polystyrene resin)

Fig. 10 again compares the two regenerants on an "equivalent hydrogen" basis in the treating of Lake Michigan water. While the water quality produced through the use of the two acids in the treating of this water (Table 7) was very comparable, approximately 50 per cent higher capacity was obtained by use of hydrochloric acid, as is shown in Table 8.

TABLE 7

Cations (as $CaCO_3$)	Ppm	%	Anions (as $CaCO_3$)	Ppm	%
Calcium	85	59	Bicarbonate	109	76
Magnesium	43	30	Sulfate	19	13
Sodium	15	11	Chloride	15	11
Total cations	143		Total anions	143	

TABLE 8

Regenerant	Lb per cu ft	Capacity, kgr as $CaCO_3$	Lb of acid per kgr
H_2SO_4	4	14–15	0.26
HCl	3 (100 per cent acid), no recycle	20.5–21.5	0.14

A detailed report was made at this conference a year ago covering a large industrial demineralization plant which employs hydrochloric acid for the regeneration of its cation-exchangers (2). The individual units are 11.5 ft in diameter and house 520 cu ft of high-capacity polystyrene resin. The cation-exchangers will average 2¼ million gallons of Lake Huron water per cycle to the sodium breakthrough point which is a capacity between 26,000 and 30,000 gr per cu ft of resin. A regenerant dosage of 6.4 lb of 100-per cent HCl per cu ft is employed at this plant which means an acid consumption of from 0.21 to 0.24 lb per kgr of cations removed. Reclaimed hydrochloric acid from the previous regeneration is utilized, which contributes to the water quality and exchange capacity obtained.

Acknowledgments

The author expresses appreciation to the Omaha Public Power District for the opportunity of obtaining and presenting the information given in Figs. 5 and 6. Acknowledgment is also made of the contribution of laboratory findings by members of our Ion Exchange Research Staff.

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(1) "Sulfuric Acid Regeneration of a High-Capacity Cation-Exchanger," John H. Kay, J. I. Bregman, A. M. Fradkin and J. S. D'Amico. Presented before the Division of Water, Sewage and Sanitation Chemistry, American Chemical Society, September 1952.

(2) "Demineralization Plant Operation Experiences," M. E. Brines, *Proceedings* of the American Power Conference, Vol. XIV, 1952, p. 406.

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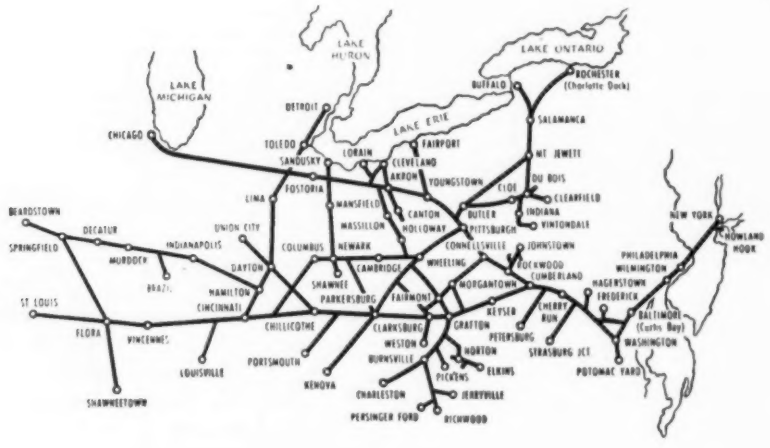

BALTIMORE & OHIO RAILROAD

Bituminous Coals for Every Purpose

Distribution of Power and Process Steam Costs in Industrial Plants

The following has been adapted from a translation[1] of an article by H. Beckmann which appeared in the February 1953 issue of *Brennstoff-Warme-Kraft*. It explains and gives an example of a method developed in Germany for allocating steam and power costs in industrial plants. The original article presents additional examples and applications.

IN industrial power plants that supply both process steam and back-pressure or condensing power, it is desirable to employ a method of allocating costs in which the rate will not depend on variations in the consumption of one or the other products. The author believes that this can best be done by calculating power in terms of its cost under condensing operation and by allowing steam to be the beneficiary of the combined production.

Determination of costs in plants which generate steam only or power only presents no problem. All expenses must be covered by charges against the product and the cost per unit of steam or power can be readily determined. Unit cost in this type of plant varies hyperbolically with load, whereas the total cost is practically a straight-line function, with its origin at the level of fixed charges and its inclination a measure of variable costs. The total cost, which amounts to the sum of fixed charges and variable costs, is not dependent upon minor effects of starting or stopping the plant nor upon load fluctuations. Basically it remains a linear function which balances out over wide load levels.

Simultaneous Steam and Power Production

Conditions become more complicated in an industrial plant where steam is supplied to process at several different pressures and at the same time power in varying amounts. In such cases the production costs of steam and power are dependent upon one another and it often becomes difficult to arrive at an equitable distribution.

The simplest case is that of a noncondensing plant which utilizes the exhaust steam for process and charges for or sells the power generated by the back-pressure turbine, or turbines, at a definite price, making an allowance for the energy used by auxiliaries. As long as there is only one process pressure involved, charge against the steam used is definitely fixed by the returns on the sale or use of power.

However, where steam is used at several pressures each must be charged separately with the back-pressure power that could have been produced by its expansion in the turbine. Because of this, high-pressure process steam becomes more expensive than low-pressure stream.

In many cases back-pressure power is accompanied by power produced by condensing units. Here allocation of costs ranges somewhere between the extremes of crediting the full economic advantage to the production of power or to the production of steam. Each may be charged according to the ratio of its thermal requirements, calculated on the basis of heat value; or the production of electric power may be calculated on the basis of the cost of condensing energy.

In practice, the author contends that calculations are useless which credit the advantage of the combined production partly or wholly to power, for in this manner the price of power becomes dependent on the ratio of steam consumption to power consumption. He therefore advocates that charges be on the basis of condensing power, so that steam receives the advantage of the combined usage. According to his theory, this method has the following justification: Under otherwise unchanged conditions, each additional kilowatt-hour must be produced as condensing power, whereas each additional pound of steam contributes to the saving effect of the combined operation through the production of back-pressure power at a much lower heat rate.

Basing the calculations on condensing power, the cost of steam is determined by the total cost less the credit for electric energy supplied. The lower the pressure, the cheaper the steam becomes.

The question then arises as to the basis for calculating the cost of condensing power. Should it be based on full load or partial load, and if the latter, at what load?

Calculation on Basis of Work Value

This question is answered by allocating the cost of steam on the basis of work value, as suggested by W. Sellin in a report prepared for the Huels Chemical Works in 1948. The calculation is based upon a condensing power plant which produces electric energy at a cost that depends on load level. If steam at any pressure is withdrawn from this power plant for external service, the user is charged with the equivalent work value which this steam could have produced had it been expanded fully. The cost of power is based upon its condensing value; and steam becomes cheaper as the required pressure decreases.

In this method the production of the plant is no longer subdivided into electric work and steam quantities of different pressures. Instead, it is simply stated in kilowatt-hours and is readily comparable with other plants having quite different relations of steam and power supply.

Apart from simplicity of calculation, this method is claimed to have the following advantages:

1. The cost of power is independent of the ratio of steam supply to power supply. Under constant price and wage conditions it changes only according to duration of supply.

[1] Translated by W. W. Schroedter, Combustion Engineering, Inc.

2. In making a comparison of power plant costs when there are varying ratios of steam and power supply, only the cost of the produced kilowatt-hours, which includes the supply of steam and its work value, need be compared.

3. Costs of steam and power are actual values, rather than being arbitrarily assigned as may be the case with other methods.

4. For process steam at different pressures, the cost takes into account the effect of pressure.

5. A breakdown into fixed and variable costs can easily be made.

6. The consumption of coal for a given output can readily be established from the sum of the consumed kilowatt-hours of power and equivalent steam for which the coal consumption in the condensing plant is fixed.

How Calculations Are Made

All costs up to the bus bars and the steam header outlet are charged to the power plant on a kilowatt-hour basis. Output therefore consists of the electric energy delivered to the bus bars plus the equivalent work value of the steam supply to all steam networks. The consumption of electric energy and regenerative steam within the power plant is not taken into consideration.

As an example, consider a simple plant operating at 20 atmospheres absolute (284.4 psia) with condensing and back-pressure turbines. Each machine is assumed to operate with an internal efficiency of 80 per cent and a combined mechanical and electrical efficiency of 94.4 per cent. The internal plant consumption is assumed to total 17 kwhr per ton.

The high-pressure steam leaves the boiler at 350 C (662 F) with an enthalpy of 748.5 kcal per kg (1350 Btu per lb). With a condenser pressure of 0.075 ata and the above-mentioned internal efficiency, the steam will enter the condenser with an enthalpy of 563.5 kcal per kg (1016 Btu per lb). Its expansion in the condensing turbine produces 203 kwhr per metric ton (2205 lb) of steam.

$$\frac{(748.5 - 563.5)\ 10^3}{860^*} \times 0.944 = 203 \text{ kwhr per ton}$$

After deduction of the internal consumption of 17 kwhr, a net power gain of 186 kwhr per metric ton remains. With extraction taking place at 4 ata (57 psia) and an enthalpy of 677.5 kcal per kg, 78 kwhr per metric ton is produced in the back-pressure turbine.

$$\frac{(748.5 - 677.5)\ 10^3}{860} \times 0.944 = 78 \text{ kwhr per ton}$$

Of this amount 12 kwhr per ton must be deducted for feed pump energy and consumption in the boiler house, thus bringing the back-pressure power gain to 66 kwhr per metric ton. The 5 kwhr per ton internal consumption for condensing need not be deducted since every ton of bled steam saves the amount required for condensing purposes.

If the 4 ata steam were to be expanded in the condensing turbine it could produce 125 kwhr per ton (203 − 78), of which 5 kwhr would be consumed for condensing. In other words, the extracted steam has a work value amounting to 120 kwhr per metric ton. In the same way the work value of high-pressure steam is calculated at 186 kwhr per metric ton, and the work value of the exhaust steam at condensing pressure is negative, namely, −5 kwhr per ton, because extraction would save the energy for condensation.

The table compares the values of steam at 4 ata and 0.075 ata for the heat-value and work-value methods. The high-pressure steam is assumed to have a value of unity. According to the heat-value method the steam at 4 ata is calculated at 90.5 per cent of that at 20 ata, while the condensing steam is valued at 75.2 per cent of the high-pressure steam. On the other hand, using the work-value method, the back-pressure steam at 4 ata is worth 64.5 per cent of the high-pressure steam and the condensing steam has a negative value of 2.7 per cent.

Applications of the Methods

The work-value method is widely used where steam and power are supplied simultaneously in condensing plants. If steam and power are supplied by a back-pressure noncondensing plant it is often expedient to use the net power gain. On the other hand, in comparing one power plant with another it is necessary to calculate with work values.

In the case of plants which both generate their own power and purchase from an outside source, there are two possibilities. If the work price of the outside power is less than that internally generated, then the outside power should always be fully utilized and the plant condensing power used to cover peaks. If the work price of the outside power is higher than that produced within the plant, then the internal generation should be fully utilized and the outside power purchased to cover peaks.

* 860 kcal = 1 kwhr = 3413 Btu.

TABLE 1—EVALUATION OF STEAM IN A 20-ATMOSPHERE PLANT

Steam Conditions	Net Power Gain, Kwhr per Metric Ton**	Work Value, Kwhr per Metric Ton†	Evaluation of Steam, D, According to Heat Value	Evaluation According to Work Value
High-pressure steam, 20 ata	−12	203 − 17 = 186	$D_{20} = 1.00\ D_{20}$	$D_{20} = 1.00\ D_{20}$
Back-pressure steam, 4 ata	78 − 12 = 66	125 − 5 = 120	$D_4 = \frac{h_2}{h_1} D_{20} = \frac{677.5}{748.5} D_{20} = 0.905\ D_{20}$	$D_4 = \frac{120}{186} D_{20} = 0.645\ D_{20}$
Condensing steam, 0.075 ata	203 − 17 = 186	−5	$D_{0.075} = \frac{h_3}{h_1} D_{20} = \frac{563.5}{748.5} = 0.752\ D_{20}$	$D_{0.075} = \frac{-5}{186} = -0.027\ D_{20}$

** Kwhr produced per ton of steam supplied.
† Equivalent condensing kwhr per ton of steam supplied.

Facts and Figures

There are over 2300 bituminous coal mines in the state of Kentucky.

•

Illinois Institute of Technology has the largest total enrollment of engineering students.

•

Approximately 89 per cent of all the steel produced in the United States is made by the open-hearth process

•

The largest oil tanker in the world was recently launched at Hamburg, Germany. It is of 45,000 tons displacement.

•

At present nearly 100 billion kilowatt-hours of electricity are consumed by incandescent and fluorescent lamps for general lighting purposes.

•

Titanium was discovered in 1791 by a clergyman named Gregor of Cornwall, England, but it was not until 1794 that it was given its present name by the German chemist, M. H. Klaproth.

•

Oil is being removed from some wells almost three miles below the surface of the earth, although actual drillings have been made to depths of more than 20,000 ft.

•

In addition to the United States, Russia and Britain, which have atomic bombs, a number of other countries have nuclear energy programs for peaceful purposes. These are Canada, France, Norway, Holland, Sweden, Belgium and Italy.

•

At one large British power station phosphatic deposits on heating surfaces, due to vaporization of phosphoric acid from the fuel bed, was overcome by introducing pulverized coal above the stokers and recirculating part of the flue gas.

•

During the past fifteen years the proved reserves of crude oil in the United States have more than doubled.

•

According to the American Petroleum Institute, the United States has increased its oil and natural gas consumption at the rate of 10 per cent a year since the end of World War II.

•

Of the eight most efficient power stations in this country, with a yearly heat rate under 10,000 Btu per kwhr, two operate at a throttle pressure of 2000 psig, four employ 1450 psig, one uses 1650 psig and one 1250 psig. All employ the reheat cycle.

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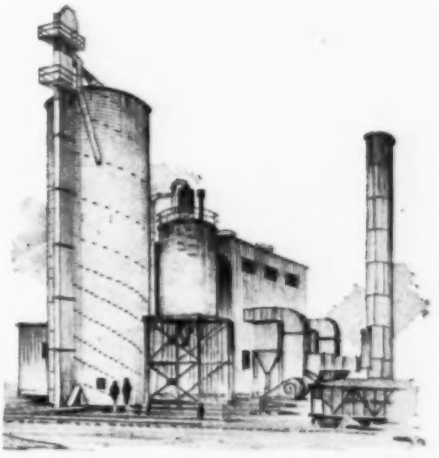

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(*Continued from page 41*)

For loads below this point the gas-turbine plant obviously would be taken off the line and the entire load carried by the steam plant. For loads above this point, the heat rate of the combined plant is superior to that of the steam or gas-turbine power plants in independent operation. The reason for this improvement in heat rate lies in the fact that the heat rejected from the gas-turbine power plant in independent operation is available in combined operation and hence does not represent a total loss. The location of the point of intersection of the two heat-rate curves appears to be a function of the deviation from the optimum condition of preheat temperature and stack temperature, brought about by a higher ratio of gas-turbine exhaust gases to preheated air in the combustion gas mixture at reduced load on the steam generator.

Conclusions

It is recognized that no absolute conclusions for a proposal of this nature can be reached on the basis of theoretical calculation alone. It is also recognized that the combustion topping unit is not universal in its application. However, the analytical investigation removes the proposal from the realm of pure conjecture and indicates clearly that the scheme is worthy of experimental investigation in those instances where the combustion topping unit seems promising. Admittedly, a careful balance must be made of the many different variables pertaining to each proposed application including the economic aspects that are peculiar to a particular plant and location.

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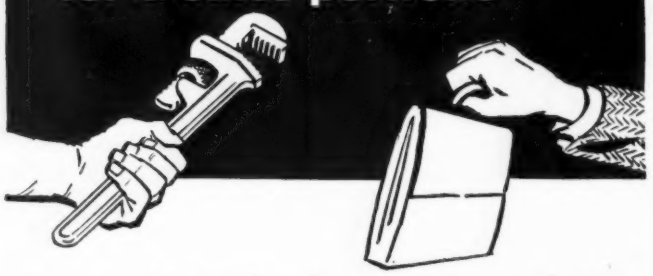

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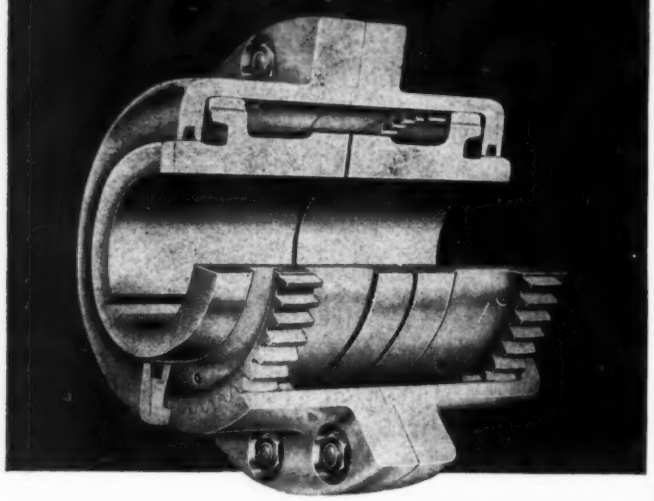

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BOILER EFFICIENCY INCREASED
AT LEAST TWO (2) PER CENT.

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Progress at Oak Creek Station

Located on the west shore of Lake Michigan about 10 miles south of Milwaukee, the first 120,000-kw unit at the Oak Creek Station of the Wisconsin Electric Power Company is now nearing completion, as shown in the accompanying construction photograph. A second unit of the same size is also under construction in this station, which will ultimately contain four units. Sufficient space is available to build a second station of similar size at the same site.

Features of the station were described by O. J. Stallkamp in a paper before the 1952 American Power Conference.* Items such as radiant superheaters and reheaters, bin-and-feeder firing and the single boiler-turbine arrangement which have proved themselves at the Company's Port Washington and Lakeside stations are incorporated in the Oak Creek design. New features will include cross-compound turbines, controlled-circulation boilers, vertical pumps, pressurized circulating-water tunnel and centralized control.

The feedwater cycle is designed for six stages of bleed heating. There are three low-pressure single full-size horizontal heaters located in the turbine room and three high-pressure dual half-size vertical heaters located in the boiler room.

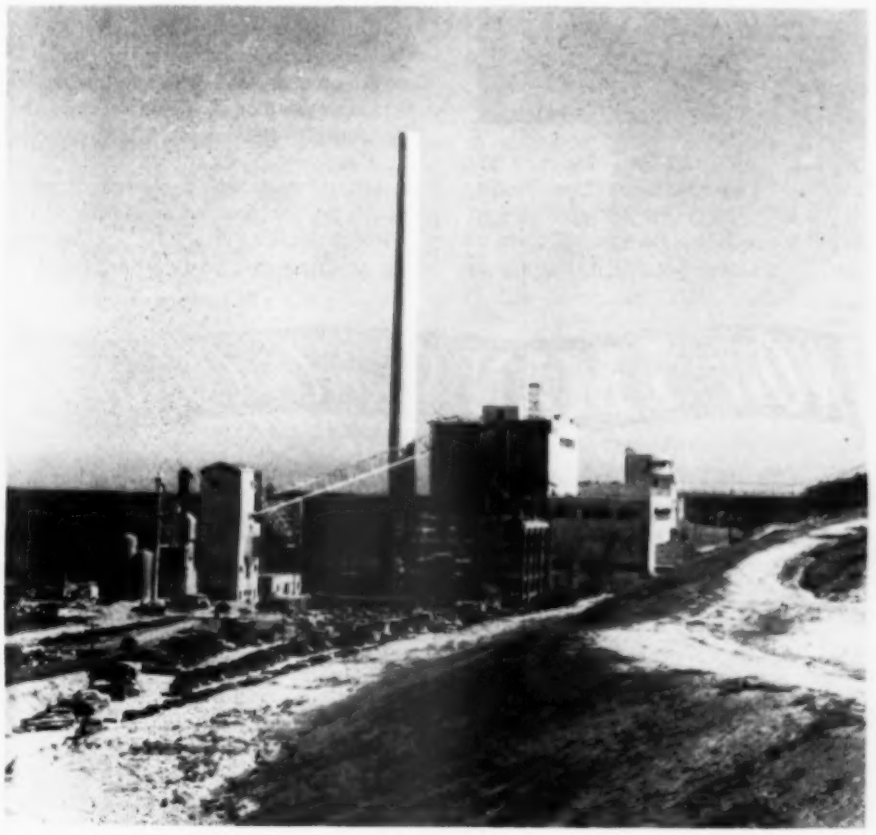
The cross-compound turbine-generator consists of an 80,000-kw, 3600-rpm high-pressure machine and a 40,000-kw, 1800-rpm double-flow low-pressure machine. Tied together electrically, the generators will always operate as a unit. Throttle steam conditions are 1575 psig, 1000 F with reheat to 1000 F.

Each turbine-generator is supplied by a controlled-circulation steam generator. There are three constant-speed circulating pumps, of which two are sufficient for handling full load. Primary superheaters have both radiant and convection surface and are connected in series. Radiant reheaters form the side walls of the furnace.

The condenser is of the single-pass type designed for operation at 0.5-in. back pressure. The shell, water boxes and tube sheets are made of steel, while the tubes are of inhibited admiralty metal.

A separate pump house is provided for the circulating-water system. It is equipped with a trash bar screen and three traveling screens. Four vertical axial-flow pumps discharge into a common tunnel under pressure to supply four condensers. By keeping the tunnel velocity to 7 ft per sec and through the use of streamlining, it has been possible to reduce pumping head to 17 ft. The discharge tunnel is a gravity type and arranged for recirculation to combat ice formation at the intake.

The station is completely housed except for the induced-draft fans, dust collectors and breechings. This type of construction was dictated by the severity of the winter climate in the area. Building design is functional without architectural ornamentation. The gross volume of the boiler and turbine rooms amounts to about 19 cu ft per kw rating.



Construction as it appeared in July at Oak Creek Station

* *Proceedings* of the American Power Conference, Vol. XIV, 1952, pp. 234–240.

New Kanawha River Steam Plant in Service

The first unit of the new Kanawha River Station of the Appalachian Electric Power Company, about 20 miles upstream from Charleston, W. Va., was recently placed in service and on August 18 was the object of an inspection trip by over a hundred newspaper, radio and television representatives.

This unit is of 200,000 kw rated output and a second of like capacity is scheduled to go into operation late this year, thus bringing the initial station capacity up to 400,000 kw at a cost of approximately 46 million dollars. Steam conditions are 2075 psi and 1050 F total steam temperature. The plant will burn over a million tons of southern West Virginia coal per year which is equivalent to the output of 720 miners, each working five days a week for 50 weeks and mining an average of six tons a day. In total miners' wages this represents $2,880,000 yearly.

The new station serves not only the Kanawha Valley, but also the Company's service area in West Virginia and Virginia. Also, as an integral part of the American Gas and Electric System, of which Appalachian Electric Power is a subsidiary, it serves indirectly an area extending over portions of seven states.

Connection with the AEG System is through 132,000-volt transmission lines, also by the first 330,000-volt line to be built in this country. This first link of a 330,000-volt transmission network, which will eventually connect all the major plants and load centers of the system, is a 63-mile line from the Kanawha Station at Graham, W. Va. This line has also been extended to the new Muskingum River Station of the Ohio Power Company, near Beverly, Ohio. A third 330,000-volt line is under construction in the territory of the Indiana and Michigan Electric Company, an AGE affiliate.

The Kanawha River Station is the fourth major generating station to be placed in operation on the AGE System during the past eight years. Counting the first Kanawha unit, the system capacity is now 3,219,000 kw and an additional 920,000 kw is building.

Personals

Charles L. Hulswit has been elected president of the Rockland Light and Power Co. to succeed the late Fremont L. Lovett who was killed in an airplane accident on June 13.

Herbert B. Reynolds who has been associated with J. G. White Engineering Corp., New York, following his retirement from the New York City Transit System in 1949, has severed connection with the former and will devote his time to consulting engineering.

Dr. Adolph Meyer, retired chief engineer of Brown Boveri Co., will be awarded the George R. Henderson medal by Franklin Institute on October 21, for outstanding accomplishments in the field of gas turbines.

C. M. Garland, well-known Chicago consulting engineer, announces that he will resume his practice after a prolonged absence. He will carry on this work from his country estate in Ingleside, Ill.

Walter A. Bowers has been made assistant manager of the Business Department of Burns & Roe, New York engineers and constructors.

Edgar E. Cobb has been made engineering manager of Westcott & Mapes, architects and engineers, New Haven, Conn. He has been with that organization for the last three years as chief of its electrical division.

Dr. W. C. Schroeder has resigned as assistant director in charge of programming at the U. S. Bureau of Mines and will teach chemistry and chemical engineering at the University of Maryland. Joining the Bureau in 1933, he became assistant chief of the Fuels and Explosives Division in 1939 and in 1945 was made chief of the Synthetic Fuels Branch.

Largest Hot-Process, Hot-Zeolite Softener

The photograph shows the unique design of what is claimed as the world's largest hot-process, hot-zeolite water softener, which is installed at the Bayway, N. J., refinery of the Esso Standard

Oil Co. This unit was designed and built by Graver Water Conditioning Co., and handles 200,000 gph of feedwater for 650-psi boilers. Known as the "Sphericone" because its shape combines a sphere and cone, it is 60 ft high and 43½ ft diameter at the largest cross-section. Its special shape provides distinctive advantages in obtaining clearer and softer water.

Obituary

James McDonnell, assistant manager in charge of erection of the Service and Erection Department of Combustion Engineering, Inc., died suddenly on August 14 at the age of 66. A native New Yorker, he was educated in the public schools of that city and prior to World War I served a number of years in the regular U. S. Army as an enlisted man, rising to the rank of top sergeant, and during the war as a commissioned officer with the rank of captain. Between army enlistments he served a short period in the Navy and also as an operating engineer in stationary power plants. He joined the Combustion organization in 1920 as an erector and was made district superintendent of erection in the Pittsburgh district in 1925, moving to the New York office in 1930 as assistant manager in charge of erection. At the time of his death he resided in East Orange, N. J. Surviving are his wife and two daughters.

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Large size approximately 1400/1600 CFM. Give complete description with details including make, serial number, price, age, location, condition.

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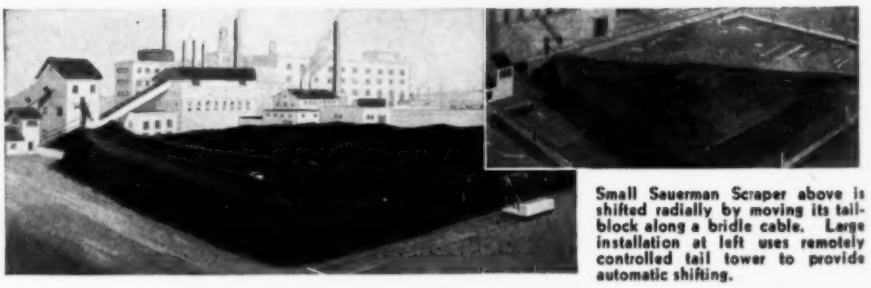

Small Sauerman Scraper above is shifted radially by moving its tail-block along a bridle cable. Large installation at left uses remotely controlled tail tower to provide automatic shifting.

with a **SAUERMAN POWER SCRAPER**

Speed up coal storage the easy, efficient way—with a "one-man" Sauerman Power Drag Scraper. Any tonnage can be handled readily with maximum utilization of any size area. The operator needs little training . . . his job is easy and working conditions are comfortable.

The improved Sauerman System insures you against spontaneous combustion, too. The pile is built by spreading one thin layer of coal on top of another and the bottomless Crescent scoop sifts the fines into the voids as it moves across the pile—thus eliminating air pockets.

Consider, also, the fact that Sauerman Scrapers are reasonable in first cost and maintenance averages less than ½¢ per ton handled. Just two more of the many reasons why Sauerman equipment is your best buy.

Write today for the Sauerman Coal Storage Catalog

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Business Notes

L. J. Wing Mfg. Co. announces that Charles H. Smith has been named vice president in addition to his duties as secretary in which capacity he has been serving since 1943. Also, Thomas R. Harden has joined the Wing organization as a mechanical engineer in its heating and ventilating sales department.

Builders Iron Foundry, Providence, R. I., which was incorporated just a hundred years and subsequently became widely known as a manufacturer of water meters, venturi tubes and other measuring instruments, as well as filtration equipment, has just changed its name to B-I-F Industries, Inc. The reason is that at present the term "foundry" has little relation to such equipment put out by its subsidiaries, Builders-Providence, Inc., %Proportioneers, Inc.% and Omega Machine Co.

Allis-Chalmers Mfg. Co. has named Clyde R. Braun manager of its nuclear power section. He was formerly assistant to the manager of the company's power department.

The Carborundum Co. has elected Theodore H. Booth a vice president. He joined the organization in 1952 as general manager of the Bonded Products and Grain Division, prior to which he was assistant vice president of Walworth Co.

Chain Belt Co. of Milwaukee announces that W. C. Messinger, assistant to the manager of its Construction Machinery Division, has been made secretary of the company to fill the vacancy left by the retirement of George D. Gilbert, after 35 years service with the organization.

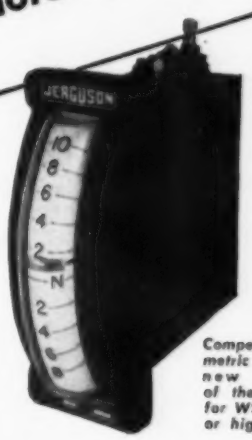
The Bayer Co. has appointed the DeHavern Engineering Co. as its representative in the Indianapolis territory and the Homan Equipment Co. in the Cincinnati territory.

Copes-Vulcan Division of the Continental Foundry & Machine Co. has appointed C. H. Spencer & Co., Salt Lake City, Utah, as its representative in that territory for its boiler controls and instrumentation by Taylor.

Foster Engineering Co., Union, N. J., has named Chester S. Beard as research and development engineer in connection with its automatic regulators for control of pressure and temperature.

Check the Liquid Level From Anywhere in the Room

with the NEW CONVEX SCALE Jerguson TRUSCALE Remote Reading Gage



Compensated Manometric Gage meets new interpretation of the boiler code for WSP of 900 psi or higher.

Scale Markings directly on convex face. Indicator clear around convex surface. Full 180° Visibility without distortion.

You get full 180° visibility . . . so you can read the liquid level from any point from which you can see the gage . . . with the New Convex Scale now available on Jerguson Truscale Remote Reading Gages. You can stand at one end of the control room and instantly check your whole line up of Truscale Gages.

Jerguson Truscales give you instant remote readings of liquid levels of boilers, deaerating tanks, etc. . . . with the amazing accuracy of ½ of 1% of scale reading. And with the New Convex Scale you make these readings from any angle . . . accurately, without distortion. Truscales available with lights, horns and Truscale Repeaters.

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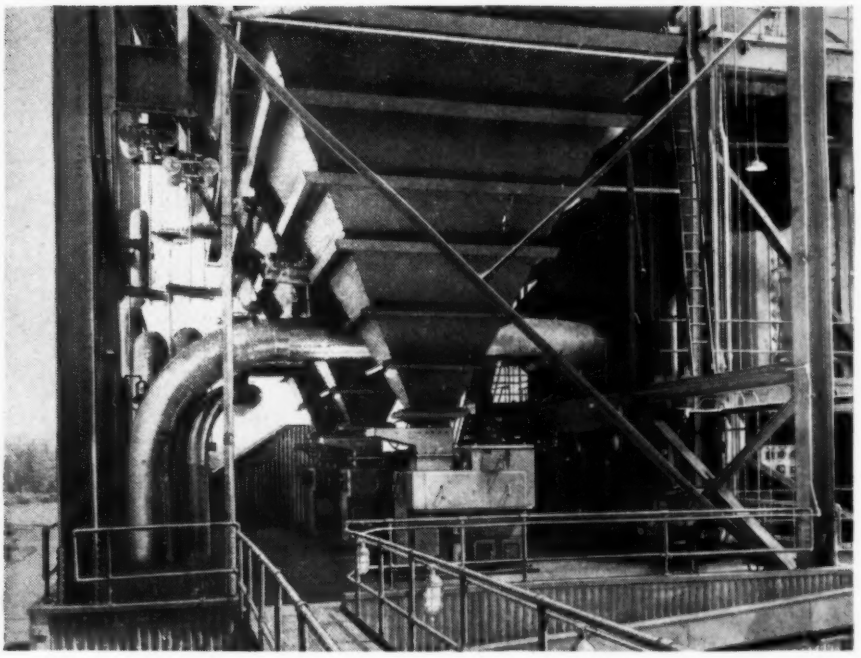
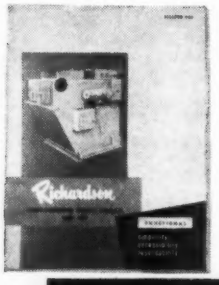
Richardson

Richardson Automatic Coal Scales are playing a vital part in helping supply power for the new Industrial South. Here are Richardson Model 39's in an outdoor installation at the new generating station of Carolina Power and Light.

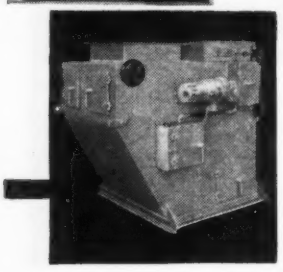


To both industrial and utility power generating stations, specifying Richardson means—

1. A 24" x 24" inlet opening and 26" wide belt for maximum coal flowability.
2. All wiring and controls outside coal chamber.
3. Access doors which will not spill dust on floor when opened.
4. Beam ratio test facilities outside coal chamber.
5. Gravity operated by-pass, with no restriction of coal flow to downspout.
6. No drag links or wires attached to weigh hopper.
7. Nationwide after-delivery service.



Latest development in the 39 Series of Richardson Automatic Coal Scales is the Model H-39 shown below. May we send you our new 16-page engineering data book on the H-39 Coal Scale (Bulletin 0352), without cost or obligation?



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Annual Water Conference Program

The Fourteenth Annual Water Conference sponsored by the Engineers' Society of Western Pennsylvania will be held at the Hotel William Penn, Pittsburgh, October 19 through 21. Papers and discussions scheduled for the program are as follows:

Monday morning, October 19

"Development of Water Treating at Refineries of Esso Standard Oil Company and Affiliates," by L. H. Zepfler and J. C. Hill, Esso Standard Oil Co.

Monday afternoon, October 19

"Filter Aid Filtration of Water," by G. R. Bell, Johns-Manville Research Center.

"Mixed-Bed Deionization," by W. S. Morrison, Illinois Water Treatment Co.

Tuesday morning, October 20

"Experiences With Corrosion and Depositions Controls for Cooling Tower Systems in an Oil Refinery" by L. N. Scharnberg and E. F. Lynch, Gulf Oil Corp.

Tuesday afternoon, October 20

"Factors Influencing Metal Loss in Condensate and Feedwater Systems," by S. Adkins, National Aluminate Corp.

"Iron and Copper Deposits in Boilers," by R. C. Ulmer, Combustion Engineering, Inc.

"Effect of Sulfite Treatment of Boiler Water on Condensate pH," by John W. Purssell, Jr., Boston Edison Co.

"Comparison of Ammonia, Amines and Hydrazine," by Prof. F. G. Straub, University of Illinois.

"The Use of Cyclohexylamine for Control of Condensate and Feedwater pH," by J. D. Ristroph, Virginia Electric and Power Co.

"Experiences With Ammonia and Cyclohexylamine at the Springdale and Mitchell Power Stations," by E. L. Jacobs, West Penn Power Co.

"Precautions in the Use of Ammonia and Amines," by E. A. Yorkgitis, Hall Laboratories, Inc.

"Analytical Methods for pH, Iron, and Copper," by R. F. Andres, The Dayton Power & Light Co.

Wednesday morning, October 21

"Steam Purity Observation at Institutional Power Plants," by Russell W. Lane, Illinois State Water Survey.

"Recent Advances in Chemical Cleaning," by P. H. Cardwell, Dowell Incorporated.

Wednesday afternoon, October 21

"Gadgets," by Dr. E. P. Partridge, Hall Laboratories, Inc.

ASME Fall Meeting in Rochester

The program has been announced for the Fall Meeting of the American Society of Mechanical Engineers, to be held October 5 to 7 at the Sheraton Hotel, Rochester, N. Y. Among some fifty technical papers and talks the following should be of specific or general interest to power engineers:

At the President's Luncheon on Monday noon, the president, Frederick S. Blackall, Jr., will talk on ASME Standards.

Later, at 5 p.m., the Calvin W. Rice Lecture will be given by J. Foster Petree, editor of *Engineering*, London. His subject will be "The Position of the Technical Press in Relation to Industry."

At 8 p.m. the Junior Group will hold a session with "Engineering—Opportunity Unlimited" as the discussion topic. The scheduled speakers are A. M. Beebee, president of the Rochester Gas & Electric Corp., and C. J. Hudson, consultant to the Norton Company.

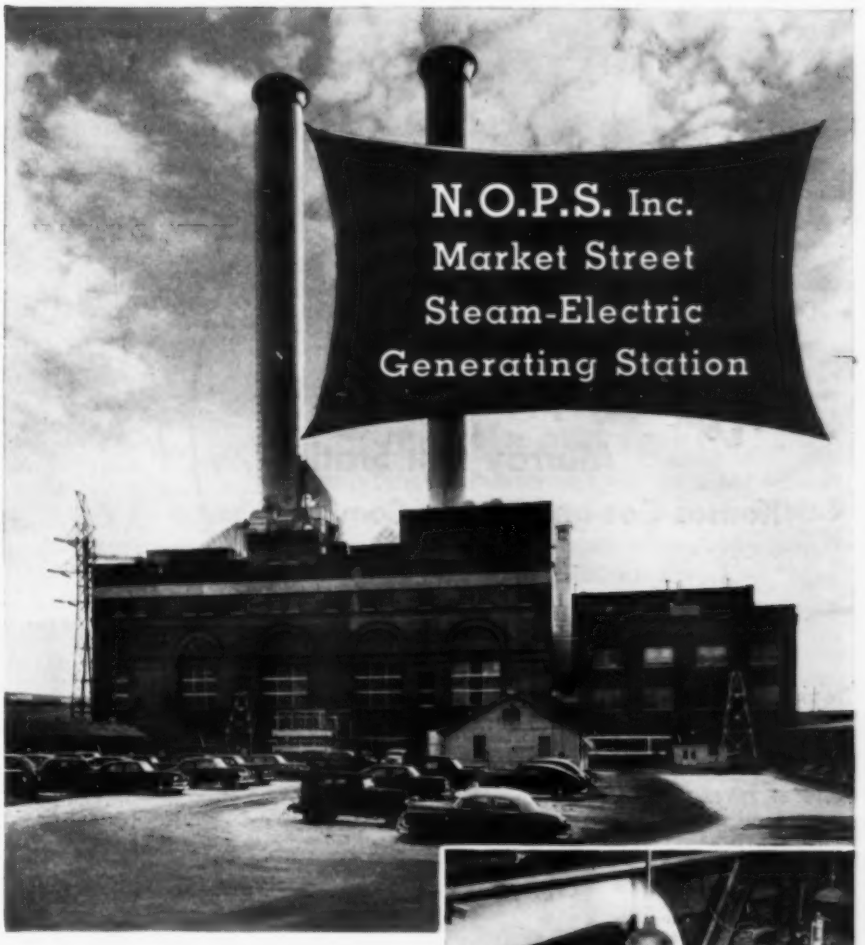
The first Fuels Session, Tuesday morning, will have three papers, namely, "Cyclic Catalytic Reforming of Natural Gas," by G. L. Calderwood of Rochester Gas & Electric Corp.; "Properties of Residual Petroleum Fuel" by W. Sacks of McGill University; and "Coal and Ash-Handling Features at Milliken Station" by H. C. Schweikart of Gilbert Associates, Inc.

The joint Rochester Engineerng Society and ASME Roy V. Wright luncheon on Tuesday will be addressed by Carey H. Brown, manager of engineering services at the Eastman Kodak Park Works. His topic will be "Engineering Manpower."

On Tuesday afternoon the Power Session will include papers on "Design Considerations in Kodak Park's Power System" by H. A. Decker of Eastman Kodak Co.; "Design and Operaion of High-Recovery Regenerative-Type Air Preheaters" by A. D. Bradden and Joseph Waitkus of the Air Preheater Corp.; and "Centrifugal Boiler-Feed Pumps Under Transient Operating Conditions" by I. J. Karassik of Worthington Pump Corp., G. H. Bosworth of Bechtel Corp. and W. D. Elston of Pacific Gas & Electric Co.

The banquet will be held on Tuesday evening with Edward P. Curtis, vice president of the Eastman Kodak Co. presiding.

The second Fuels Session is scheduled for Wednesday morning and will consist of three papers, namely, "Lighting Off and Starting-up Precautions for Stoker-Fired Boilers" by H. W. Andrews of Eastman Kodak Co.; "Laboratory and Field Experience with Heating Oils" by R. P. Gilmartin of Gulf Oil Corp.;



2 Foster Super-Jets replaced 10 old style safety valves

Unit #17 showing the 2-3" Foster Super-Jets which replaced 10-4" old style safety valves which were mounted on Y bases to each of the drum nozzles visible. The Foster valves are set at 400 and 410 psig respectively.

As part of the New Orleans Public Service Inc. modernization program at their Market Street Steam-Electric Generating Station, they replaced 10 old style 4" safety valves with 2-3" Foster Super-Jet Safety Valves.

If you are planning to modernize a plant, it will pay you to consider installing Foster Super-Jet Safety Valves. The installation can be made at minimum cost with absolute protection against overpressure.

For further information, ask for Bulletin 80-SV.

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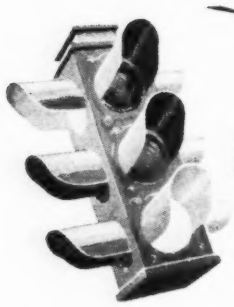

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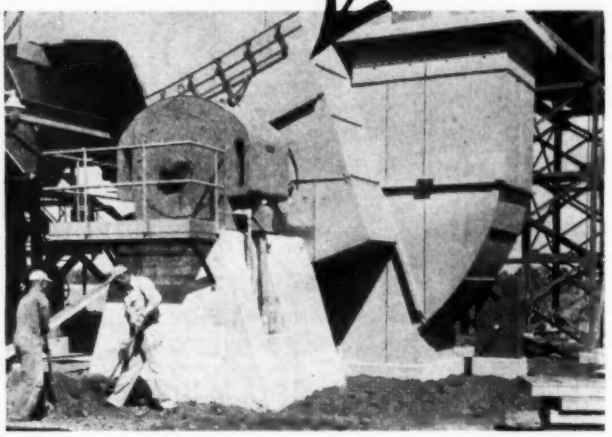
Design capacity 256,500 cfm @ 383°F. 28.65" Bar; 10.16" SP; 705 RPM 595 HP. Special control type louvre inlet dampers; outlet dampers; inlet boxes; air-cooled bearings and sun shields.

The installation includes a Green Forced Draft Fan.



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We have been designing and making draft fans for 48 years. This is indicative of our experience. We have supplied fans for many of the leading utility and industrial power plants now under construction or recently completed. This is indicative of our modern designs and fabricating methods.

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and "Installation of Fuel-Gas Piping on Premises of Industrial Consumers" by E. L. Spanagel of Rochester Gas & Electric Corp.

Two papers are listed for the Power Session on Wednesday morning. They are "Design and Operation of Russell Station" by I. G. McChesney of Rochester Gas & Electric Corp.; and "Turbine Starting and Loading Tests at Dunkirk Station" by R. C. Wiley and S. M. Kratz of General Electric Co.

Also, for those interested in instruments and regulators, mention should be made of a session on Wednesday afternoon at which the following papers will be presented: "Study of Cubic Characteristics Equation by Root-Locus Methods" by Y. Chu of Ford Motor Co.; "The Study of Transients in Linear Feedback System by Conformal Mapping and the Root-Locus Method" by V. C. M. Yeh of Gulton Mfg. Corp.; and "Static-Flow Characteristics of Single- and Two-Stage Spring-Loaded Gas-Pressure Regulators" by A. S. Iberall of Aero Equipment Corp.

Inspection trips for the men will be made to the Eastman Kodak Park Works, the Mixing Equipment Co., the Pfaudler Co. and Russell Station of the Rochester Gas & Electric Corp. For the ladies there will be a tour of Kodak Park Works, a bus tour of the city, an evening at George Eastman House, a style show and a trip through Letchwork Park.

Instrument Society Meeting

The Eighth Annual Instrument Conference and Exhibit is to be held in the Morrison and Sherman Hotels in Chicago, Illinois, September 21–25. This gathering, sponsored by the Instrument Society of America, will include sessions under the auspices of the ASME, AIEE, IRE, and the Scientific Apparatus Makers Association. An attendance of over 15,000 is expected for the technical sessions, the instrument maintenance clinic and the exhibition by about 200 companies having activities in industrial instrumentation. The following papers on the program should be of interest to engineers in the steam power field:

Monday, September 21, 2:00 p.m.

"Steam Turbine Supervisory Instruments," by J. C. Spahr, Westinghouse Electric Company.

"Steam Turbine Supervisory Instruments" by R. L. Jackson and E. Uses, General Electric Co.

Wednesday, September, 23, 9:30 a.m.

"Human Engineering in Power Plant Instrumentation" by John G. Fleming, The Bristol Co.

"Instrumentation of Steam Power Plants" by Herman H. Johnson, Consolidated Edison Co. of New York.

"A Wide-Range Flow Controller" by A. A. Kalinske, Infilco Inc.

Wednesday, September, 23, 2:00 p.m.

"A Combustion Guide and Safeguard of the Gas Analyzer Type" by J. E. McEvoy, Bailey Meter Co.

Corrosion Engineers to Meet October 7–9

The South Central Region of the National Association of Corrosion Engineers will hold its Annual Meeting at Tulsa, Okla., October 7 to 9. The program includes two discussion sessions and thirteen technical papers. The former will deal with pipeline corrosion and oil and gas transportation, whereas the latter will cover petroleum corrosion inhibitors, hydrogen sulfide corrosion, cathodic protection of underground lines, and corrosion in processing plants. The tentative schedule of technical papers is as follows:

Wednesday morning, October 7

"Evaluation of Inhibitors for Gas Lift Wells," by D. A. Shock and J. D. Sudbury.

"Use of Pearson Bridge for Evaluating Corrosion Inhibitors," by Norman Hackerman and B. I. Cross.

"Electrochemical Studies of the Hydrogen Sulfide Mechanism," by Scott Ewing.

Thursday morning, October 8

"Pipeline Corrosion Forum:"

"Cathodic Protection of Bare Pipelines in High-Resistance Soils," by R. C. Martin.

"Economics of Pipeline Corrosion Mitigation," by L. C. Sharpe.

"Cathodic Protection of Plant Yards with Distributed Anode Systems," by P. J. Whitney, Jr.

Thursday afternoon, October 8

"A Study of Factors Affecting Heat-Resistant Coatings," by Joe Pench.

"Corrosion of Centrifugal Gas-Compressor Phosphor Bronze Oil-Sealing Sleeves," by E. C. Greco.

"Gasket Surface Corrosion," by E. V. Kunkel.

Friday morning, October 9

"Elevation of Ammonia for Control of Hydrogen Sulfide Vapor-Zone Corrosion," by A. C. Broyles and R. C. Sammer.

Best by Test and Performance

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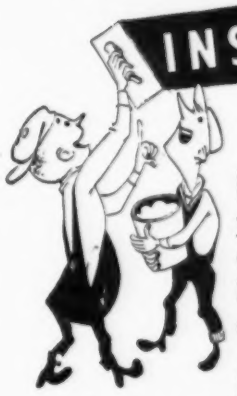

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Applied to any required thickness over any clean surface—hot or cold—Stic-Tite quickly drives to an air-tight, strong, resilient, tough covering that stays on. It does not lift off or shake loose, even under vibration, abrasion or impact in normal operation.

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Stic-Tite is truly economical. It covers at least 45 sq. ft., one inch thick, per 100 lbs. of material.

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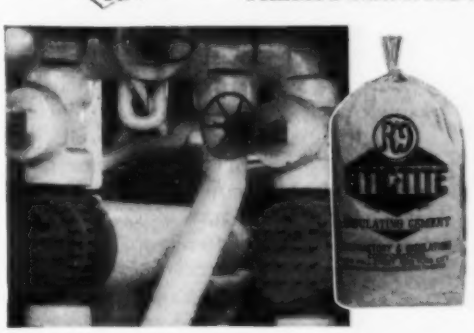

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REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N.Y.

Mechanical Engineering Thermodynamics

By David A. Mooney

A vast amount of very readable information is contained in the 540 pages of this book. While written primarily as an instruction text, it is also well suited to the needs of the practicing engineer as a reference book. This is traceable to the author's background which inolves both teaching at MIT and as principal mechanical engineer with a well-known firm of consulting and designing engineers in the power plant field.

Although a limited amount of elementary calculus has been employed, principally in connection with process calculations, this need not detract from the readability of the text by those who may have become rusty in mathematics, for the various explanations are clear and logical. In general, the order of presentation follows basic concepts of work and heat, statement of principles, data on substances, and engineering applications.

The first and second laws of thermodynamics are explained at length, and the twenty-five chapters include those on properties of pure substances, gases and steam; also discussion of various cycles, nozzles and orifices, steam turbines, internal-combustion engines, gas turbines and refrigeration. All of these are amply illustrated by diagrams, and the text is in line with up-to-date practice as concerns pressures, temperatures and reheat.

An appendix contains tables on different gases, combustion data, conversion units and specific heats of gases, as well as properties of air, steam, ammonia and mercury. Also, a number of large working charts are contained in a jacket. These deal, in part, with pressure-enthalpy for freon, temperature-entropy for air, a Mollier diagram for steam, temperature-entropy for CO_2, products of combustion and theoretical fuel-air mixtures.

The price of the book is $9.35.

Gas Turbine Analysis and Practice

By B. H. Jennings and W. L. Rogers

A well-balanced presentation of engineering fundamentals applicable to aircraft and stationary gas turbines is set forth in this new text by two professors of mechanical engineering at the Technological Institute of Northwestern University. Beginning with a brief history of internal-combustion engine and turbine development, the authors next take up thermodynamics and air properties including air tables at low pressures expanded from those prepared by Prof. Thomas E. Butterfield for *Steam and Gas Engineering* by Butterfield, Jennings and Luce. Then follow chapters on gas-turbine cycles and thermodynamics analysis; types and design features of gas turbines, and axial-flow, centrifugal and displacement compressors. Jet engines and applications for aircraft propulsion, stationary plants and various transportation services are described. Concluding chapters are concerned with fuels and the combustion process, stresses in gas-turbine elements, vibration and balancing, and materials and metallurgy.

Stress throughout the book is on fundamental concepts as the basis of design. A comprehensive bibliography of reference material is included in each chapter. There are many illustrative and example problems, as well as some for reader solution.

The text as a whole is exceptionally well illustrated. It contains 487 pages and sells for $8.50.

Measurement Techniques in Mechanical Engineering

By R. J. Sweeney

It is the purpose of this book to provide information on measurement techniques commonly used in performance testing of power equipment. The test equipment described is not limited to mechanical quantities but includes electrical measurements as well. The book provides a good background on principles of instrument design and tells how to avoid many of the difficulties ordinarily encountered in making the measurements described.

An introductory chapter takes up the problem of measurement validity, including factors affecting accuracy of readings. Physical measurements of size, mass and velocity are next discussed. There is a fairly comprehensive treatment of basic electrical measurements, including bridge circuits and methods of calibration. Advantages of various types of dynamometers are explained, following which are chapters on pressure and temperature measurements, fluid flow, calorimetry, chemical analysis and automatic controls. For almost all of the measurement techniques described schematic diagrams have been included to show either instruments or basic circuits. In many instances there are bibliographic references to more extensive descriptions in engineering papers or publications of manufacturers.

The book can best be characterized as a survey of most measurements needed for performance testing of power equipment. It is primarily suitable for teaching courses in mechanical engineering laboratory techniques but will also be found useful as a reference book for practicing engineers. The author has had a varied career including teaching, consulting, a 12-year period in the U. S. Navy, and industrial assignments in the steam power field.

Containing 309 pages, the book sells for $5.50.

Les Diagrammes Enthalpie-Entropie. Applications a L'air et aux Gaz de Combustion

By P. Chambadal

This is a French publication intended for gas turbine designers. The author is director of research for Électricité de France and has written two earlier works on gas turbines.

There is a 50-page paper-bound text which explains the use of the enthalpy-entropy diagrams, provides some theoretical background on gas turbines and tells of the thermodynamic properties of gases. Other sections give a brief study of combustion and describe how the tables are constructed.

Chart I shows enthalpy-entropy relationships for 1 kg of air over a range of 0 to 320 C. Chart II is a diagram for the determination of completion of combustion and the properties of combustion gases. Chart III is a plot of the enthalpy-entropy relationship for one kmol of air or combustion gas over a range from 0 to 1000 C.

The tables and text sell for $3.00.

Pumps

By F. A. Kristal and F. A. Annett

Second Edition

This book covers pumps of many types and designs, how to select and install them, how to operate and maintain them, and how to locate and remedy pump troubles. Intended for use by designers, manufacturers, sales representatives and operators, it discusses a wide

NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request

Protective Relaying

A 72-page illustrated booklet (GET-1768A) entitled "The Art of Protective Relaying" has been published by the General Electric Co. It contains information on types of relays used for protecting such apparatus as generators, transformers and transmission lines. Procedures are outlined for evaluating power apparatus and system characteristics to determine proper application and settings of relays.

Pressure and Vacuum Gages

Minneapolis-Honeywell Regulator Co. has prepared a 32-page catalog (No. 7001) which describes many types of gages used to measure vacuums as great as 10–11 mm of mercury and pressures as high as 150,000 psi. It covers indicators, recorders, pneumatic and electric controllers and pneumatic transmission.

Flowrator Meters

"An Introduction to Flowrator Meters" is a 16-page catalog prepared by the Fisher & Porter Co. It presents a comparison between variable-area and variable-head meters. How the variable-area meter works, its basic flow equation, as well as information on calibration scales, metering range, permanent pressure loss, upstream piping effects, viscosity effects, purging and pulsating flow are all discussed.

Boiler Feed Control

Copes-Vulcan Division of Continental Foundry & Machine Co. has issued Bulletin 1013 which illustrates and describes the Copes Type 3-L boiler feed control, a three-influence instrument type for high-duty boilers. It combines the scientific balance, characterized ports and dependability of the Copes control valve with the responsiveness and accuracy of instrumentation by Taylor.

Piping Information

The first issue of a new house organ published by Taylor Forge & Pipe Works is a 48-page publication which tells of the company's products and plants, explains how to keep up to date on codes and standards, and reprints tables of allowable stresses from the ASME Boiler and Pressure Vessel Code. Sections of the ASA standard code for pressure piping are also reprinted, and several pages are devoted to brief reviews of recent technical papers and standards.

Proportioning System

A six-page bulletin prepared by Richardson Scale Co. pictures and describes the company's recently developed proportioning and materials handling system for automatically making up formulated mixes of bulk products. Called Select-O-Weigh, the system uses a single automatic scale to cumulatively weigh different products. The bulletin explains the operation of the electronic control system, discusses rates, accuracies and goes into the possibilities of remote recording. Also explained is the actual formulating operation, the selecting, feeding, weighing and mixing.

Portable and Panel Indicators

Complete information about how manually operated portable and panel indicators are being used to measure temperature, electrolytic conductivity or pH is contained in a 24-page catalog, "L & N Manually Operated Indicators for Temperature, Electrolytic Conductivity and pH Measurements," just published by Leeds & Northrup Company. This publication describes the design and operating accuracy of these indicators which are direct reading in terms of the variable under measurement. Circuit diagrams show how they operate. Choice of equipment is made easy by listing in tabular form all specifications for both the indicators and accessories. Besides pictures of each indicator, the catalog also contains typical installation photographs.

Ion Exchangers

To summarize the properties of most of their ion exchangers and indicate some of their uses, a 12-page bulletin (No. 2508) has been prepared by the Permutit Company. The bulletin details a general history of ion-exchange engineering, gives data on the proper selection of ion exchangers and lists general applications in the treatment of water and special problems associated with the recovery of valuable metals from solutions.

Oil Burners

The Preferred Utilities Manufacturing Corp. has just published an eight-page bulletin covering the extended line of Preferred Model B and BR, belt-driven, horizontal, rotary-type, heavy-oil burners. Detailed descriptions are included in Bulletin No. 175-G of the dual-pump reservoir, fuel regulator, high-speed, belt drive, precision air-oil control, ignition pilot, fuel feed to atomizer, and extra long nozzle. Complete specifications, computed at 70 per cent thermal efficiency, are also given for both types of burners.

Deaerating Heater

Construction features of the Allis-Chalmers jet-tray deaerator (Type K-114) are described in a four-page leaflet (28R7980) released by Allis-Chalmers Mfg. Co. According to the bulletin, the deaerator offers combined advantages of a spray-type, direct-contact, first-stage heater performing as a direct-contact vent condenser and primary deaerating mechanism, a second-stage steam jet atomizer, and a final tray-type deaeration section with reboiling action.

Pump Recirculation Control

Control systems for protecting high-capacity centrifugal boiler pumps during low load conditions is the subject of a 12-page bulletin published by Republic Flow Meters Co. By recirculating water through the pump during minimum flow conditions, the systems prevent the pump from overheating and binding at the joints. Both electrically and pneumatically operated control systems are discussed. Operation and arrangement of each system is fully described and illustrated. Valves and control equipment for each system are also pictured and specifications given.

Unit Regulator

A new eight-page bulletin on the Askania Unit Regulator has just been released by the Askania Regulator Co. The Unit Regulator is a self-contained hydraulic controller engineered for automatic pressure, flow and proportioning control. The bulletin describes the operating principles and different models of the unit. It shows application diagrams and gives specifications.

Oil Burners

A condensed 16-page catalog prepared by Ray Oil Burner Co. lists commercial and industrial oil and combination gas-oil burners, including: fully automatic, semi-automatic and manually controlled horizontal rotary and steam turbine-

(continued on page 70)

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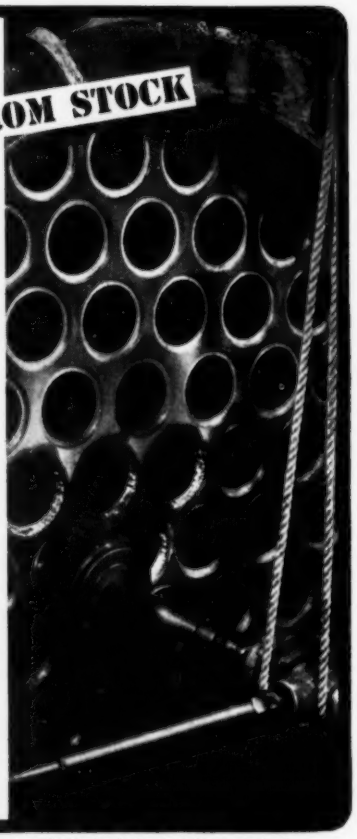
Photo courtesy of The M. W. Kellogg Co., Inc.



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drive burners; commercial and domestic pressure atomizing types for oil, gas or combination gas-oil. Specifications and capacities are also given.

Cast and Steel Chain

An "Abbreviated Catalog" on Rex cast and steel chain, cast tooth sprockets, belt conveyor idlers, and spray nozzles has just been released by the Chain Belt Co. of Milwaukee. The 56-page book has a useful, pictorial index on the inside front cover. The story of corrosion and abrasion-resistant Rex Z-Metal is presented. Chain listings and prices are given along with sprocket information. Take-ups, buckets, idlers, spray nozzles, and chain attachments are also listed.

Pipe Fabrication

A detailed description of how pressure piping is fabricated for industrial use is the subject of a 16-page brochure just released by Western Piping Supply Division of the Lummus Company. Titled "Meet Western Piping Supply," the booklet takes the reader on a pictorial tour through the company's East Chicago, Indiana, fabricating plant. Illustrations show various assemblies being made from carbon and alloy piping, and demonstrates the bending of large-diameter, heavy-wall pipe.

Deaerating Heaters

A bulletin on spray-type deaerating heaters has been published by Graver Water Conditioning Co. It explains the specific functions and requirements of deaerating heaters, describes their design and operation in detail, and outlines the accessory equipment for best results. The illustrations include complete sectional drawings and representative installation photographs of both horizontal and vertical designs, together with flow charts of units in typical applications.

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BOOKS

—Fuels and Combustion

By M. L. Smith and K. W. Stinson

330 pages Price $6.50

This textbook has as its worthy objective the presentation of fundamental and factual information concerning solid, liquid and gaseous fuels and the problems associated with their combustion. It covers the general topics of fuel technology and the relationship of air, fuel, combustion products and the heat released. The book is basically intended for undergraduate engineers studying a fuels and combustion course which would follow work in fundamental thermodynamics and precede the applied courses in steam power, internal combustion engines and heating and ventilating. However, the practicing engineer will find much valuable data compiled in concise form.

The opening chapter is devoted to all types of fuels. Then follows a very understandable treatment of stoichiometric analysis and thermochemical analysis. The process of combustion, including its mechanism and the manner of flame propagation, is next considered. Succeeding chapters take up physical properties of fuels, gas and oil burners, coal-burning equipment, and combustion in engines. An appendix includes a number of useful charts to aid in combustion calculations. At the end of each chapter there appears a list of stimulating questions and problems.

2—Steam Power Stations Fourth Edition

By Gustav A. Gaffert

637 pages 6 × 9 Price $8.00

This well-known book was first brought out in 1937 primarily to familiarize mechanical engineering students with steam power equipment and practice; but aside from fulfilling this objective, it has found wide favor among practicing engineers.

That it has been found expedient to bring out four editions over a period of fifteen years attests to the rapid developments that have taken place in power plant practice during that period. In general, statistics, data and other information have been brought through 1950, which is about as late as can be expected in view of the time required for revision, proofreading and production. Three new chapters have been added, namely, a general discussion of power equipment, heat transfer and optimum cycles.

This fourth edition contains 433 illustrations and charts, including a Mollier Diagram, and many tables.

3—Elementary Heat-Power Second Edition

By H. L. Solberg, O. C. Cramer and A. R. Spaulding

624 pages Price $6.50

The three authors have collaborated in the revision of this text which places its basic emphasis upon fuels as sources of energy, the functions of the equipment used for power generation, the construction of such equipment, and its actual performance. It is intended for the students who have studied physics and chemistry at the college level and whose mathematical training includes the calculus.

The major changes made in revising the book were directed toward bringing together as many fundamental concepts as were logically feasible in the opening chapter entitled "Matter and Energy." To these ends, consideration was given to a discussion of the English engineering system of units and dimensions, development of the general energy equation and its application to heat-power equipment in terms of the first law of thermodynamics, early introduction of the concepts of entropy and enthalpy, and the significance of the second law of thermodynamics in relation to energy degradation. The material on combustion calculations was rewritten with the purpose of stimulating analytical thinking and developing facility of calculation using the pound-mole. Descriptive material in the text has been brought up to date.

4—Technical Calculations in Heat Engineering

By James H. Potter

Paper-spiral-bound Price $2.25

Occasionally one comes upon a workbook intended primarily for student use in engineering schools that also has considerable value to the practicing engineer. Such is the case in this instance, for Professor Potter's book should be of considerable aid to the active engineer whose thermodynamics has become "rusty" and who wishes to make a systematic review, guided by a logical outline. The book contains 150 problems in heat engines and thermodynamics, one to a page.

5—The Science of Flames and Furnaces

By M. W. Thring

416 pages Price $6.50

Major emphasis of this British book is upon industrial furnaces. The author is head of the physics department of the British Iron and Steel Research Association and has also served on the staff of the British Coal Utilization Research Association.

The book tells how furnaces are built and how they function. Applications of the first and second laws of thermodynamics to furnace design are cited, and the rate and mechanism of heat release from fuels is considered. Sections are devoted to heat transfer and to the aerodynamics of hot systems. Two concluding chapters deal with the science of furnace construction and the application of scientific method to furnaces.

This book is primarily intended for the combustion research specialist rather than for the power plant designer.

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